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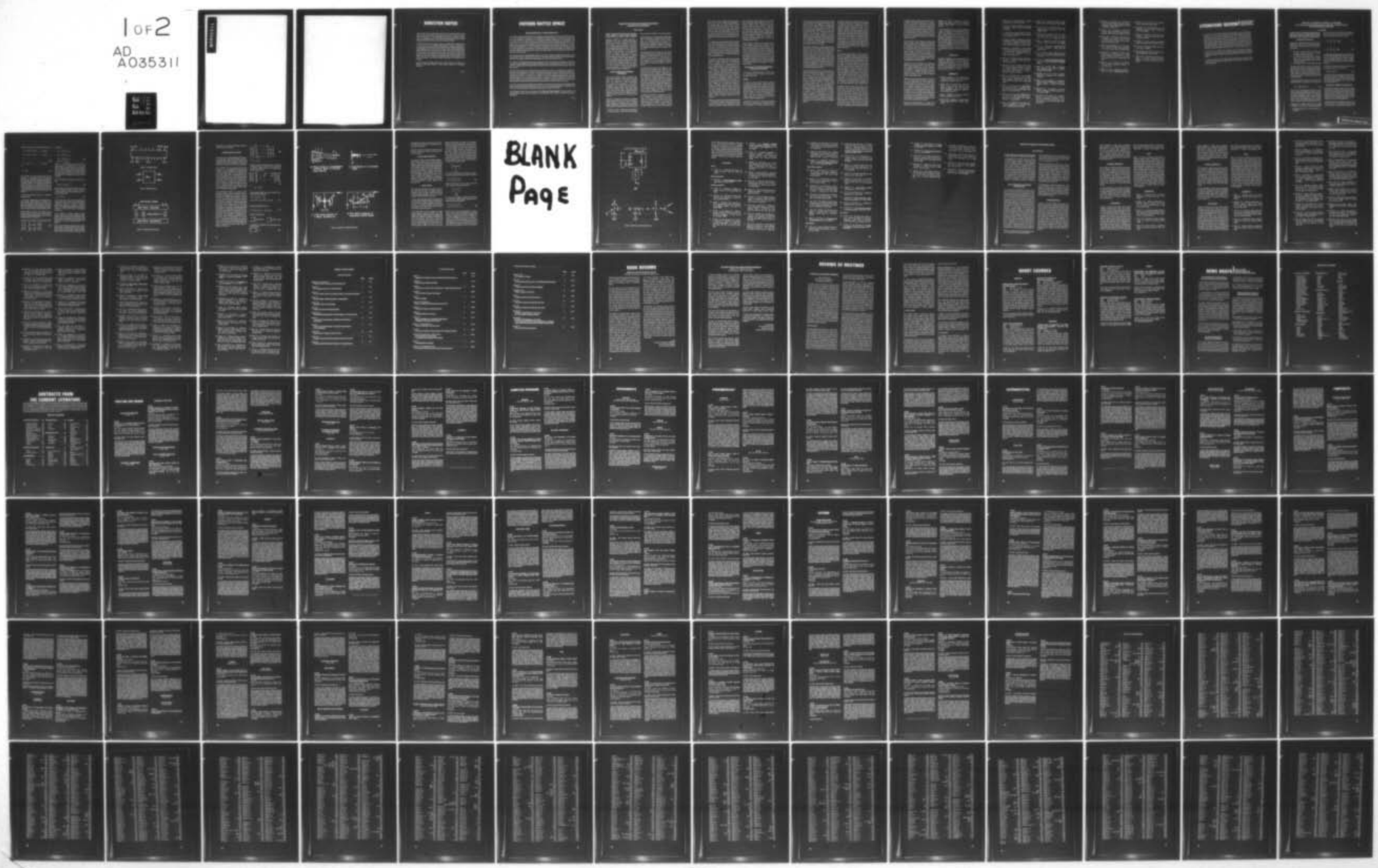

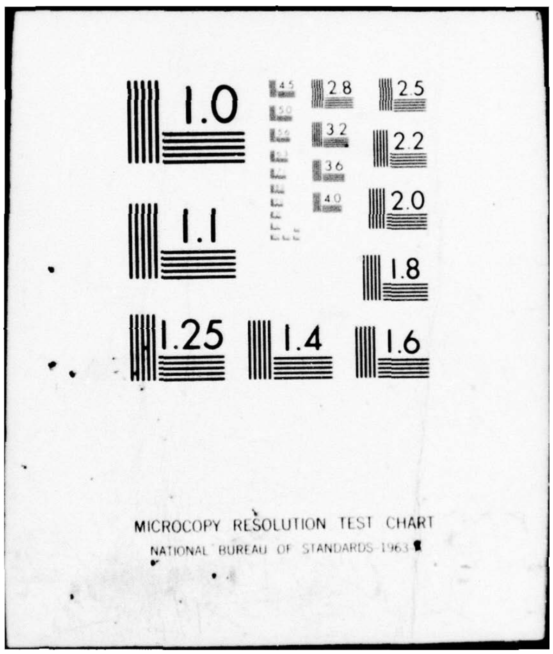
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DIRECTOR NOTES

With this issue, we are completing our eighth year of publication. During the past year we have seen significant composition improvement. Dr. Eshleman and the Vibration Institute are to be congratulated for producing consistently excellent copy. Unfortunately, some of the issues have been spoiled a bit by less than desirable printing quality. We are now trying to solve this problem.

The 47th Symposium is now history, and very successful history indeed. Thanks is due to our host, The Defense Nuclear Agency, principally represented by Dr. Eugene Sevin, who was instrumental in organizing the excellent opening session. Commendations are due for the SVIC staff--Rudy Volin, Gordan Showalter, and Barbara Szymanski--who carried out the onsight responsibilities. Special thanks to Carol Healey who minded the store at home. She is like the astronaut who goes to the moon, but must remain in orbit while the others land. A special fond "thank you" to my wife, Sallie, who managed the well received program for the ladies in attendance. I, as well as the ladies, appreciated her volunteering to fill this need.

We look forward to another useful year of service. Until then, I extend to all readers my very sincere wishes for a happy Holiday Season and a prosperous New Year.

H.C.P.

EDITORS RATTLE SPACE

THE PROLIFERATION OF "NONSTANDARD DATA"

I had occasion to take part in several informal conversations during the recent 47th Shock and Vibration Symposium. The conversations revolved about an increasingly troublesome problem: the validity of physical data. The problem parallels the development of computer-implemented data storage banks. I am not saying that most of the data are no good. Rather, there has been inadequate documentation. Standard test procedures are nonexistent. There is thus no way to describe the exact conditions under which data have been taken -- nor can the limitations and applicability of the data be stated. Many engineers must use data from the literature to characterize physical phenomena. They are understandably apprehensive about applying data that may have been haphazardly gathered and then deposited in a computer data bank. The use of such data in the design process could have disastrous consequences. Unfortunately, the design engineer is not even aware of the potential misapplications that could occur.

The American Society of Testing Materials (ASTM), the American National Standards Institute (ANSI), and the trade associations have of course done their share in developing standard procedures for data collecting and recording. It is a truism, however, that the data takers far outnumber the standards workers!

The question of nonstandard data arose at the Symposium when it was noted that a standard on material and component damping characterization is needed. Researchers and practicing engineers alike admit that most of the profusion of damping data now appearing has limited application to problems other than those for which the data were taken.

My view is that, somehow, more engineers should be persuaded to be active in the development of standards -- particularly in data acquisition. It is a fact of life today that engineers are forced to seek direct solutions; there can thus be no investment of manpower in secondary effort (payable years later). It appears that this lack of foresight could force us, in the near future, to discount much of the available published data for other than specified problems. Such a situation can be avoided by increasing our efforts in standards activity. Computer analysts complain to me that no damping data exists. In my opinion, they should take the time to define what they need; then the experimentalists could collect meaningful data in an organized and rational manner.

In summary I believe that every engineer has an obligation to be aware of standards activity: the designer should define the data he needs; the analyst should outline a form for the data that meshes with his analytical techniques; and the experimentalist should standardize data taking and range of applicability.

This concludes the eighth year of publication of **The Shock and Vibration Digest**. The editorial staff of the DIGEST wishes to make this journal as useful to you as possible. Your comments on means for improving it are solicited.

R.L.E.

VIBRATION CONDITION MONITORING TECHNIQUES FOR ROTATING MACHINERY

Brian Dawson*

***Abstract** - This paper reviews vibration monitoring techniques currently available for rotating machinery. Applications of these techniques to bearings and gears are described.*

Condition monitoring of rotating machinery is increasingly being used in preventive maintenance. Because such monitoring is based on the condition of the machine -- commonly referred to as on-condition or condition-based maintenance -- rather than a pre-determined maintenance interval. The technique requires reliable determination of the condition of machinery during operation. Various parameters are used; for example, power and efficiency; oil, coolant, and bearing temperatures; oil pressure and contamination; and vibration and noise measurements. A discussion of the complete range of monitoring techniques is beyond the scope of this article. It should be clearly recognized, however, that vibration monitoring techniques comprise only part of a condition monitoring program and that detailed study and appraisal of all possible techniques is necessary before a program is begun [1-5].

TYPES OF VIBRATION MONITORING TECHNIQUES

The simplest vibration condition monitoring technique is the measurement of the overall root mean square level of velocity or acceleration at selected points. The vibration level, called a discriminant, is an indicator of the condition of the machine. Comparison of the measured level with values on a standard vibration severity chart allow assessment of the machine [6-8]. These general tables do not provide for the dynamic response of specific machines, but they are useful in assessing the acceptability of machine operation and indicating impending failure.

Downham and Woods [9] developed an impedance testing technique that can be used with vibration severity tables. This technique allows a relatively realistic interpretation of changes in vibration levels and modification of operational criteria in accordance with the dynamic stiffness of the machine bearings.

Another technique is to measure shaft displacement using noncontacting sensors at 90° angles from each other. The resulting Lissajous and time domain signals give an indication of shaft unbalance, misalignment, and subrotational instability. Signals from noncontacting transducers mounted with respect to the bearing housing should be interpreted carefully [10].

The above techniques are useful, but they provide only a limited amount of diagnostic information. (Diagnosis has been defined as the art or act of identifying the condition of a machine from its signs or symptons [11].) The intent is to determine the condition of the machine through the analysis of its vibration without the necessity for visual inspection.

One approach that provides some diagnostic information involves measuring vibration levels in octave or one-third octave bands for one or more similar machines in the 'as new' condition. Departures from these baseline data can be used as criteria for assessing the condition of operating machinery. This technique, based on full octave band vibration measurements, has been successfully used by the Canadian Navy [12] to monitor the main propulsion and principal auxiliary equipment installed in all classes of the destroyer fleet and the submarine and maintenance support vessel equipment associated with weapons and operational systems. Techniques that can be used for one-off assessments of machine condition are called condition checking techniques.

If baseline data and failure experience are not available, machinery can be monitored either continuously or at known intervals. A decision on the condition of the machine is based on the trend of the discriminant; that is, whether or not the vibration level is increasing. The rate of change of the discriminant before failure must be slow enough to

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allow prediction of an impending failure and shutdown of the machine, however. Data obtained by the Canadian Navy [13] indicate that the mean level of a signature component as a function of time is generally a straight line having a slight positive slope for 75% of a machine's useful life; after this point the slope rises exponentially to the point of failure. The interval from the beginning of the exponential increase to failure, called the lead time, makes trend monitoring a viable maintenance procedure.

It is perhaps worth mentioning that, although condition monitoring resulting in on-condition maintenance is the prime objective of condition monitoring techniques, it has been argued [4] that the techniques encompass much more; for example, condition monitoring should be used during machinery installation. Condition monitoring techniques should also have an important role in product development [14] and quality control.

The number of diagnostic techniques for condition monitoring is large; a useful chart of possible transducers, processing procedures, and discriminants has been published [15]. Investigations into the use of vibration signature analysis techniques for diagnosis of power trains of army helicopters resulted in the division of discriminant selection into two types: condition monitoring procedures based on pattern recognition techniques and those dependent on mechanical techniques [15]. Pattern recognition techniques utilize statistical differences to determine discriminants; a disadvantage, however, is the large amount of data required before the techniques can be considered valid. These data are not always presently available, but it is hoped that increasing interest in condition monitoring will stimulate the establishment of data banks of vibration information for good and bad machines. Pattern recognition techniques developed for gears and bearings have been briefly described [15], and a number of investigators [16-20] have been working on the development of pattern recognition techniques for fault diagnosis.

Mechanical diagnostic techniques select discriminants on the basis of dynamic analysis, which provides information concerning such characteristics of the system as component natural frequencies, rotational whirl frequencies, forces, deflections, and accelerations. Time domain signal signatures from the measurement transducer must be transformed into the frequency domain before frequency components can be used as discriminants. A simple technique for achieving this transformation is to pass the vibration time domain signal through a tunable band-pass filter. The individual frequencies isolated depend on the bandwidth and shape of the filter and the particular frequency discriminants obtained. A manually tunable band-pass filter is a useful and inexpensive approach [21].

Often, however, a number of discriminants within a small frequency range must be monitored; in this case an analog band-pass filter technique is time consuming. Fortunately, this problem has been overcome by the development of the real time spectrum analyzer (RTA); frequency spectra can be obtained in a few milliseconds. Digital time compression of the vibration time domain signal allows very rapid determination of spectra. The spectra either can be permanently recorded on an X-Y plotter or processed further with a digital computer. Ensemble averaging of the spectra allows the enhancement of signals buried in noise.

APPLICATION OF CONDITION MONITORING TO ROTATING MACHINERY

Components of rotating machinery to which condition monitoring has been applied include rolling bearings and gear trains.

Bearings

The failure of ball and roller bearings -- assuming proper design and maintenance -- usually results from subsurface fatigue caused by the high cyclic contact load between the balls or rollers and the race. Surface fatigue spalls or any other surface defect disturb the rolling motion. The result is growth of the defect area, an increase in friction, and ultimately an increase in wear rate. The defect area eventually becomes so large that the bearing no longer functions properly, and serious damage occurs.

Local defects in the inner or outer race of a bearing are hit by the ball each time it passes over them. A surface defect on the ball will also strike the

inner or outer race. The rate at which these impacts occur depends upon bearing speed and location of the defect. Formulas are available to calculate these rates [22, 23]. In addition, vibrations corresponding to the waviness of the ball and races, as well as high frequency resonant frequencies of the races, can be calculated [24]. The vibration time domain spectrum of a local defect of the ball or race is a repetitive ringing transient response. The actual response pattern depends upon the structural transfer function between the source and the measurement point. Diagnostic techniques based on this type of response include narrow-band low-frequency analysis and high-frequency analysis.

Narrow-band low-frequency analysis depends upon the fact that the race pass frequencies and their harmonics become prominent as a bearing fault develops. With properly functioning bearings the shaft frequency and its harmonics dominate. A successful application of the low frequency technique has been reported [23], but use of the method is limited because noise discrimination is poor in the presence of other mechanical signals. This analysis is therefore suitable only for detecting faults in simple rotating assemblies in which the vibration is caused by the bearing or for quality control purposes in special ball bearing test rigs [25].

High-frequency analysis of the ring frequencies associated with bearing housing response to local faults appears to be much more sensitive to the bearing fault condition and is not sensitive to background noise. A ringing frequency of a bearing housing indicates a bearing fault. Several investigators have developed successful diagnostic techniques based on ringing frequency [26 - 31]. An instrument called a shock pulse meter monitors bearings on the basis of the ringing principle. The ring frequency is the natural frequency of the measurement transducer ($\triangleq$ 38 KHz). The shock pulses produced by a defect are detected by the accelerometer. The bearing condition is assessed by measuring the rate of shock emissions relative to the amplitude of the pulse. The detection of defects by measurement of acoustic emissions produced by growing cracks is a developing science, and it is already being applied to bearings [26, 32].

Monitoring techniques for detecting bearing faults have been directed at local defects. Faults described as distributed effects--e.g., misalignment, lack of roundness, unequal ball diameters--must, also be detected, however, especially in quality control situations. Vibration monitoring has been used to predict defects in gyros for spacecraft [27]; vibration signatures were predicted from mathematical models. The 'initial' bearing defects were modeled as disturbances of the force pattern so that the dynamic radial deflection at the stationary bearing ring could be determined. The solution involved several series of modulated tones; frequencies and modulation patterns depend on the initial defect. Seven out of eight known distributed defects were detected and identified correctly.

Gears

The dynamic characteristics and failure modes of gears are so radically different to bearings that a new set of mechanically related diagnostic techniques have been developed. A pair of mating gears running at constant speed and load generate a periodic vibration signal at the meshing frequency. Assuming perfect gears, the meshing vibration signal responses would not change during a complete rotation of the gear. In practice, the mesh time domain vibration response depends on a number of factors: gear profile; load; speed; stiffnesses of gear, gear tooth, shaft, and bearing; and eccentricity. The condition of gears depends upon the way in which these parameters affect the overall mesh vibration response characteristic. The nature of the excitation sources at tooth contact and the identification of tooth contact frequency components and their sidebands for spur and helical gearing have been presented [34].

Gear defects used in condition monitoring have been classified as local and distributed defects [27]. Local defects are defined as defects that occur on one or more teeth but are not uniformly distributed among the teeth. Examples are cracked, deformed, or scored teeth. A local defect manifests itself only when the damaged tooth is in mesh. Detection is thus relatively simple: inspect the time domain signal of a complete revolution of the gear; if extraneous noise is reduced by signal averaging during one revolution of the relevant gear wheel, the mesh of a damaged tooth can easily be detected.

A distributed defect causes a response that occurs throughout the complete meshing cycle. A common example is nonuniform load distribution on the teeth due to eccentricity of a gear shaft. Loading varies during one revolution of the gears; the resulting mesh time domain signal appears as a carrier frequency at the mesh rate, and amplitude modulation occurs at the rotational frequency. Periodic variations in pitch error and torque fluctuations can also cause both amplitude and frequency modulation of the mesh frequency [34, 35].

A gear condition monitor based on a time domain signal summation (signal averaging) technique has been described [27]. Local defects were determined by a crest factor analysis. (In normal gear tone, with all tooth meshes equal in shape and amplitude, there is a specific ratio of peak to amplitude, tooth mesh response changes are reflected by a change in the ratio.) Distributed defects were indicated by the percentage modulation of the gear tone. The application of the monitor to a complex gear assembly has been described, and fault conditions were successfully detected and interpreted [27].

Investigators have demonstrated that distributed defects in gear boxes give rise to modulation of the tooth meshing vibration and that the modulation can be detected in the frequency spectrum [36, 37]. The detection of sidebands caused by frequency modulation can be aided by the application of the spectrum technique, which has been successfully applied to gear vibration [38].

Steward has summarized gear diagnostic techniques [47]. He interprets gear condition by analyzing a narrow-band power spectrum, a time domain signal summation based on an average period of one revolution of the gear under study, and wear trend based on a logarithmic difference plot between relevant components of the measured spectrum and a baseline spectrum of the new assembly. Secondary transformation of the time domain signal average results in a dynamic error signature (which essentially indicates abrupt changes in the character of the time domain signal) An instantaneous frequency plot is also useful in identifying fault conditions.

Narrow-band spectrum-analysis of a vibration time domain signal can be used to indicate faults due to unbalance, oil whirl, misalignment, mechanical looseness, seal rubbing, belt slip, and structural resonance. Useful diagnostic charts are available [21, 39].

It has been said that condition-based maintenance is likely to become the accepted description of a rational new approach to preventive maintenance [40]. Condition monitoring techniques must be related to maintenance planning and hence to the uncertainty associated with the maintenance program. The basic problems involved in handling condition monitoring systems include deciding whether or not to test and establishing analytical techniques for dealing with uncertainty. There is also uncertainty in interpreting test results, particularly with regard to the analysis of noise and vibration measurements [41].

CONCLUSION

A number of vibration analysis techniques are now available for detecting and identifying defects in rotating machinery. Most of the work to date has concentrated on developing mechanical diagnostic techniques. For large organizations with the capability for building data banks, pattern recognition techniques may be of value in the future.

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LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critque and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

In this issue of the DIGEST Alan Hannibal's article on Modeling of Vibrating Systems is continued. He gives an overview of approximate methods, mechanical impedance and mobility, transfer matrix method, finite element methods and bond graphs.

In the second review article, Professor Robert Plunkett of the University of Minnesota briefly describes recent developments in instrumentation used to measure shock and vibration.

MODELING OF VIBRATING SYSTEMS - AN OVERVIEW

Part II. Approximate Methods, Mechanical Impedance and Mobility, Transfer-Matrix Method, Finite Element Methods, and Bond Graphs

A. J. Hannibal*

A number of prominent modeling methods are presented in capsule form. The "type" of modeling technique is emphasized rather than details of the method. The references have been divided into sections relating to the modeling methods.

APPROXIMATE METHODS

Approximate methods are used to model distributed systems within a finite number of degrees of freedom. Approximate methods are used for at least one of three reasons.

- For cases of nonuniformity in which the governing equations are difficult, perhaps impossible, to solve in closed form
- For reducing a distributed system to standard matrix form (see equation (21)), thereby making the equations compatible with discrete elements in the system
- For analyses over a limited frequency range

The approximate methods in common use include the assumed-modes method, lumped-parameter method, and the influence coefficient method. The assumed-modes method is the most flexible because it is an energy method, and generalized distributed coordinates can be used. The others usually involve geometric coordinates.

In the assumed-modes method, the response of the distributed system is assumed to be of the form

$$y(\vec{x}, t) = \sum_{i=1}^{n} \phi_i(\vec{x})\ q_i(t) \tag{18}$$

where $q_i(t)$ are time-dependent generalized coordinates and $\phi_i(\vec{x})$ are admissible functions in terms of the spatial coordinates, $\vec{x}$. That is, the functions satisfy all the geometric boundary conditions and all the criteria for differentiation. In cases of nonuniformity, either the eigenfunctions of the uniform case or a polynomial are used as admissible functions.

Substitution of equation (18) into the integral formulation of the kinetic and potential energies of the continuous system yields the energy expressions, given by equations (19) and (20). These expressions are typical of a discrete n-dimensional system.

$$T = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij}\dot{q}_i\dot{q}_j \tag{19}$$

$$V = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} k_{ij}q_iq_j \tag{20}$$

In these equations m_{ij} depends on the mass distribution and the admissible functions $\phi_i(\vec{x})$. The mass matrix $[m_{ij}]$, when derived in this fashion, is referred to as the consistent mass matrix [16]; k_{ij} is dependent on the stiffness distribution and the admissible functions.

The equations of motion can be derived directly from equation (11) and are of the matrix form

$$[m_{ij}]\ddot{\vec{q}} + [k_{ij}]\vec{q} = \vec{F} \tag{21}$$

In addition to the assumed-modes method are Galerkin's method and the Collocation method. Both derivations are based on an error function associated with the equilibrium equation. All of these methods have been discussed [17].

MECHANICAL IMPEDANCE AND MOBILITY

Impedance and mobility methods have not received the attention they deserve. The emphasis on noise pollution has stimulated renewed interest, however, because complex structures can radiate acoustic energy over a range from several hundred to several thousand Hertz. Impedance methods are used to reduce such systems to a manageable level.

Consider that the linear, nonrigid structure in Figure 3 is acted upon by n sinusoidal forces, either excitation or reaction, having the same frequency. The

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mobility equations that define the structure are

$$v_1 = m_{11}F_1 + m_{12}F_2 + \ldots\ldots + m_{1n}F_n$$

$$v_2 = m_{21}F_1 + m_{22}F_2 + \ldots\ldots + m_{2n}F_n$$

$$\vdots \qquad (22)$$

$$v_n = m_{n_1}F_1 + \ldots\ldots + m_{nn}F_n$$

or

$$\vec{V} = M\vec{F} \qquad (23)$$

M is referred to as the mobility matrix, and the elements m_{ij} are complex quantities. The diagonal elements m_{ij} are called driving point mobilities, and the off-diagonal elements $m_{ij}(i \neq j)$ are called transfer mobilities. Equation (23) essentially characterizes the entire structure at n discrete points; that is, if Figure 3 represents a nonrigid foundation upon which a vibrating machine is to be placed, only the force-velocity relationship at the points of attachment need be known.

The inverse of the mobility matrix, M^{-1}, is called the impedance matrix.

In the matrix characterization of mechanical structures, mobility is more suitable than impedance. The reason is that mobility does not require "blocked" points and, therefore, can be expanded or contracted without disturbing previous measurements or calculations. A detailed discussion has been published [18].

Closely related to mobility and impedance are the four-pole parameters, which can be used to analyze mechanical systems having a single input terminal and a single output terminal (see fig. 4).

In equation form, Figure 4 can be characterized by

$$\begin{Bmatrix} F_1 \\ V_1 \end{Bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{Bmatrix} F_2 \\ V_2 \end{Bmatrix} \qquad (24)$$

from which

$$\begin{aligned} \alpha_{11} &= F_1/F_2 \,|_{V_2 = 0} \\ \alpha_{12} &= F_1/V_2 \,|_{F_2 = 0} \\ \alpha_{21} &= V_1/F_2 \,|_{V_2 = 0} \\ \alpha_{22} &= V_1/V_2 \,|_{F_2 = 0} \end{aligned} \qquad (25)$$

where $v_2 = 0$ implies that the output terminal is blocked and $F_2 = 0$ implies that it is free. From equation (25) it is apparent that α_{12} is an impedance, α_{21} is a mobility, and α_{11} and α_{22} are transmissibilities. The four parameters are usually frequency dependent complex quantities. Fortunately, they are not dependent on the presence of any other mechanical system.

From the Theorem of Reciprocity, it can be shown that

$$\alpha_{11}\alpha_{22} - \alpha_{12}\alpha_{21} = 1 \qquad (26)$$

so that never more than three of the four-pole parameters are needed to specify the system completely. In the case of a symmetrical mechanical system, it can also be shown that

$$\alpha_{11} = \alpha_{22} \qquad (27)$$

so that only two of the four-pole parameters is needed to specify the system. Snowdon [19] presents a systematic approach to four-pole parameters; Sakata [20] applies the parameters to vibration isolation of the engine/transmission from the body of a vehicle in order to reduce noise in the passenger compartment.

In the treatment of vibration isolation between nonrigid machines and nonrigid foundations as depicted on Figure 5, Soliman and Hallam [21] neatly blend mobility representations of the machine and foundation with four-pole characterizations of the isolators.

Even though mechanical impedance and mobility measurements can theoretically be utilized to characterize complex structures using a number of discrete nodes, they are not problem free. Extreme care in the

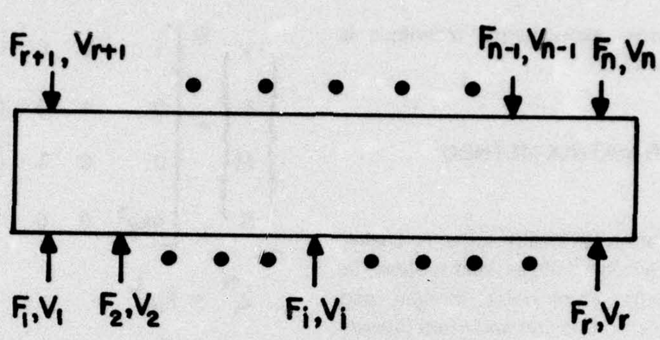


Figure 3. Nonrigid Structure

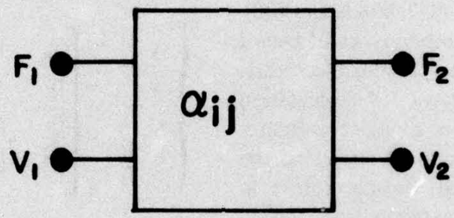


Figure 4. Mechanical System

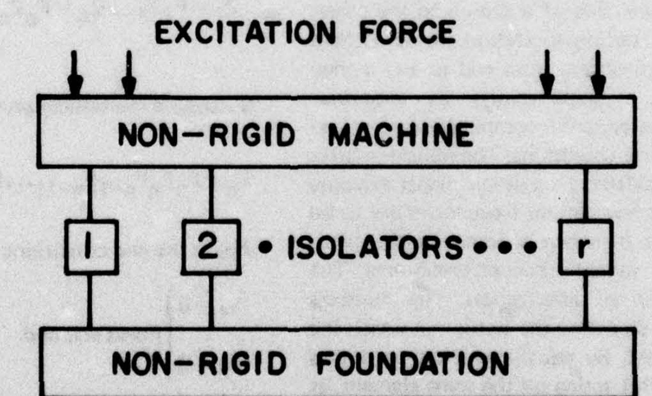


Figure 5. Nonrigid Mechanical System

adminstration of proper experimental technique is required to avoid errors [22].

TRANSFER-MATRIX METHOD

The transfer-matrix method is ideally suited to chain-like model systems. Systems such as beams, diesel- or turbine-generator shafts, crankshafts, straight and branched rotor systems, composites and multi-layered media such as soils [36, 37] fall into this category.

The foundation for the transfer-matrix method, referred to as the Myklestad-Prohl Method, was developed in the mid-1940s by N.O. Myklestad [38] to analyze airplane wings and other types of beams and by M.A. Prohl [39] to analyze flexible rotors. Both men directed their work toward the calculation of undamped natural frequencies of planar systems. Lund [40] extended their work in analyzing the orbital response of unbalanced flexible rotors in fluid film bearings. He further extended the method [41] to determine stability and damped critical speeds of a flexible rotor in fluid-film (plain cylindrical and tilting-pad journal) bearings.

The transfer-matrix method is a linear, lumped-parameter analysis in which a distributed system is divided into concentrated mass points, or stations, connected by massless elastic segments. Transfer, or point, matrices that equalize forces and moments are derived from one side of a station to the other; and matrices from station to station are called field matrices. The entire system from end to end is then accumulated into a single matrix by successive multiplications. The system is completely determined by applying only end conditions. The transfer-matrix method can be elucidated via a simple planar example for which the first few natural frequencies are to be determined. Figure 6a shows a homogeneous cantilever beam with a variable cross-sectional area. The dashed lines imply an idealization. The numbers 1, 2,....,n in Figure 6b define the stations at which the mass is concentrated. By equalizing the shear forces (S) and moments (M) acting on the mass element, as shown in Figure 6c, the point matrix shown in equation (28) is derived.

$$\begin{Bmatrix} -y \\ \theta \\ M \\ S \end{Bmatrix}_i^R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ m\omega^2 & 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} -y \\ \theta \\ M \\ S \end{Bmatrix}_i^L \tag{28}$$

or

$$Z_i^R = P_i Z_i^L$$

Equilize forces and moments as shown in Figure 6d and apply elementary strength of materials principles to derive the field matrix for the massless beam element, equation (29).

$$\begin{Bmatrix} -y \\ \theta \\ M \\ S \end{Bmatrix}_i^L = \begin{bmatrix} 1 & l & l^2/2EJ & l^3/6EJ \\ 0 & 1 & l/EJ & l^2/2EJ \\ 0 & 0 & 1 & l \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} -y \\ \theta \\ M \\ S \end{Bmatrix}_{i-1}^R \tag{29}$$

or

$$Z_i^L = F_i Z_{i-1}^R$$

Apply equations (28) and (29) consecutively from the fixed end to the free end

$$Z_1^L = F_1 Z_0;\ Z_1^R = P_1 Z_1^L;$$
$$Z_2^L = F_2 Z_1^R \ldots Z_n^L = F_n Z_{n-1}^R;\ Z_n = P_n Z_n^L \tag{30}$$

Successive multiplication yields

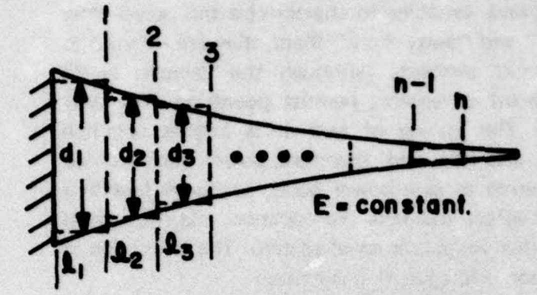
$$Z_n = P_n F_n P_{n-1} F_{n-1} \cdots P_2 F_2 P_1 F_1 Z_0 \tag{31}$$

Apply the end conditions

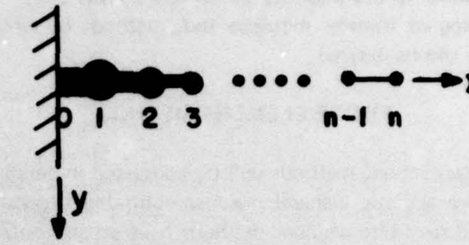
$$\left.\begin{matrix} y_0 = 0 \\ \theta_0 = 0 \end{matrix}\right\} \text{Fixed end and} \qquad \left.\begin{matrix} M_n = 0 \\ S_n = 0 \end{matrix}\right\} \text{Free end} \tag{32}$$

to calculate the undamped natural frequencies from the determinant

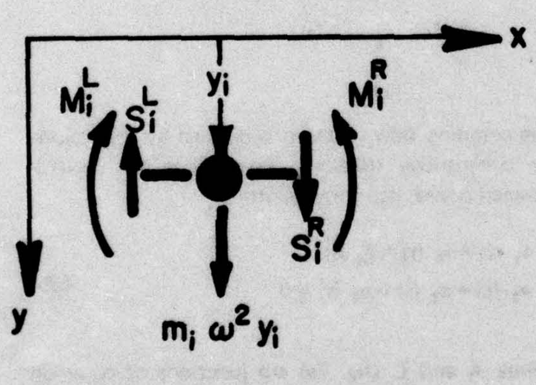
$$\begin{vmatrix} u_{33} & u_{34} \\ u_{43} & u_{44} \end{vmatrix} = 0 \tag{33}$$



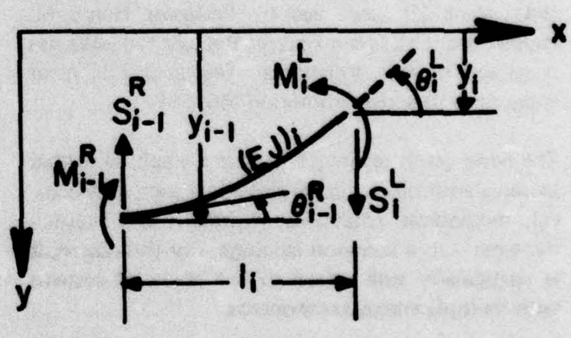
a) Planar Model of a Homogeneous Cantilever Beam of Varying Cross-Section.



b) Idealization of a Cantilever Beam.



c) Free-Body Diagram of a Mass Element, m_i.



d) Free-Body Diagram of Massless, Elastic Beam

Figure 6. Example of Transfer-Matrix Method

Although this formulation is compact, each term can be a high order polynomial of ω, requiring a numerical treatment for solution.

Included in the book by Pestel and Leckie [42] is a catalog of transfer matrices and, methods by which they can be derived.

FINITE ELEMENT METHOD

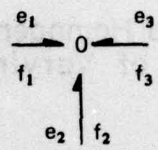
Finite element methods will be addressed in detail in future articles. General purpose computer programs based on finite element methods have revolutionized vibration analysis in general. Finite element programs can be routinely used to model rather complex vibratory systems; knowledge of how the elements are derived or assembled is not necessary. Experience is valuable, however, in element selection, grid construction, mesh density, boundary conditions, etc.... Finite element methods have allowed the reduction of complex structures to analyzable form; particularly useful are the component mode synthesis [43-46] and Guyan Reduction or "master" degrees of freedom [47, 48].

BOND GRAPHS

The bond graph approach was originally reported [54] some 25 years ago by Professor Henry M. Paynter from MIT, but only in the past ten years has it gained notable acceptance. This is due in great measure to its active promotion [55, 56].

The bond graph technique utilizes a graphical format to reduce various dynamic systems -- such as, electrical, mechanical, rotational, hydraulic, and thermodynamic -- to a common language. For this reason, it is particularly well suited to the study of systems with multiple energy components.

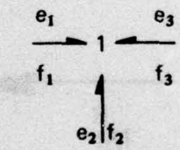
A few basic definitions will be applied to a single degree-of-freedom damped oscillator (Fig. 9a). Because bond graphs are basically an energy-power concept, the fundamental variables are referred to as effort (e) and flow (f) -- the product of which yields power. In mechanical systems, effort and flow are more commonly referred to as force and velocity; in electrical systems, voltage and current; and in hydraulic systems, pressure and volume flow rate. Because the three basic components of the oscillator (spring, mass, and damper) require only one pair of effort-flow variables to characterize the power flow "into" and "away from" them, they are referred to as 1-port elements (although the damper, or its equivalent a resistor, permits power to flow only into). The joining of two ports implies common effort and flow and, therefore, power; such a union is referred to as a power bond. In 3-port junctions either effort and flow are common, and the sum of the other variable is equal to zero. The 0-junction or common effort junction is written



It is defined by the following constitutive relations (using the inward-directed power sign convention)

$$e_1\ (t) = e_2\ (t) = e_3\ (t)$$
$$f_1\ (t) = f_2\ (t) + f_3\ (t) = 0 \qquad (34)$$

With the 1-junction or common flow junction the roles of effort and flow are interchanged.



The common flow junction is defined by the following constitutive relations, again using the inward-directed power sign convention

$$f_1\ (t) = f_2\ (t) = f_3\ (t)$$
$$e_1\ (t) + e_2\ (t) + e_3\ (t) = 0 \qquad (35)$$

Points A and C (fig. 7a) are junctions of common velocity (flow) and are represented by 1-junctions; however, as $v_{ref} \equiv 0$, point A will be ignored. The 1-junction associated with point C is shown on Figure 7b, including bonds with the spring (C_2), the mass (I), the excitation S_e (effort source), and the unbonded port (F_1, v_C). The half arrows on the port lines indicate the direction of power flow when both effort and flow are positive. Point B is a junction of

BL

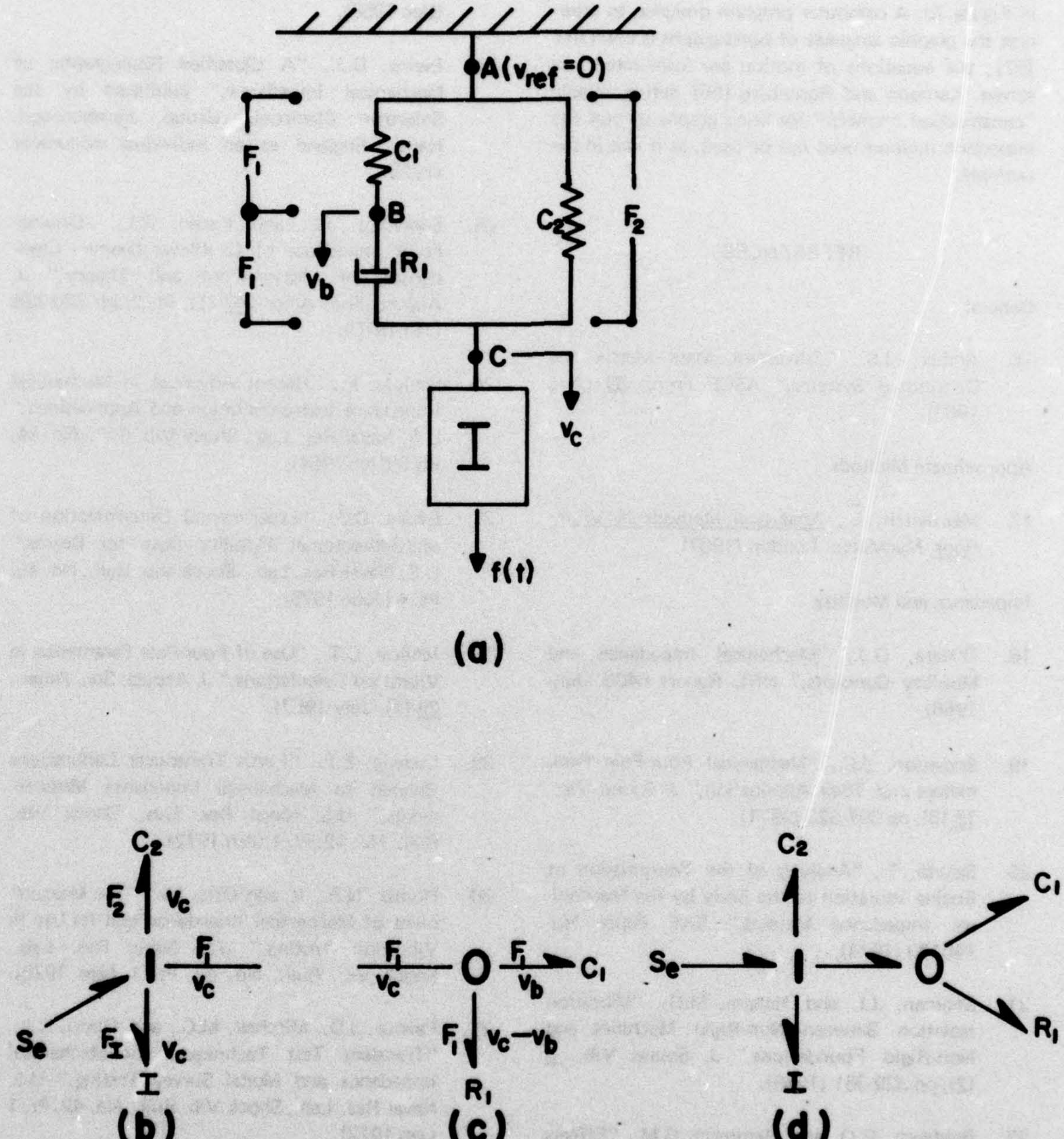


Figure 7. Bond Graph of a Damped Oscillator

common effort (force) and is modeled as a 0-junction (Fig 7c). The bond graph of Figure 7a is completed by joining the common port (F_1, v_C), as illustrated in Figure 7d. A computer program designed to interpret the graphic language of bond graphs is ENPORT [57]; the equations of motion are formulated and solved. Karnopp and Rosenberg [56] define reliable "construction methods" for bond graphs so that the inspection method need not be used, as it was in the example.

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SHOCK AND VIBRATION INSTRUMENTATION

Robert Plunkett*

***Abstract** - This article briefly describes recent developments in instrumentation used to measure shock and vibration.*

Instrumentation for measuring shock and vibration is a difficult subject to review. To begin with, there is little published literature in the conventional sense. The information that has been published is usually tutorial, written to stimulate sales, or part of some study. This article describes some of the developments that the author thinks will affect future shock and vibration instrumentation. No attempt is made to cite individual articles that are not related to the trends chosen. For the most part, instruments and systems used to measure shock and vibration are discussed; in addition, an important advance in ultrasonic nondestructive testing is mentioned.

SIGNAL PROCESSING AND SYSTEM IDENTIFICATION

The most significant development in instrumentation during the past five years has involved hard wired, digital microcomputers. The combination of microcomputers and wide range (80 dB) logarithmic amplifiers and efficient analog to digital (A to D) converters is on the verge of driving analog filters and data storage systems off the market. Even though most publications pertaining to these computers have a sales emphasis and appear in trade journals, they are well written and contain the technical information necessary for understanding the principles and limitations involved. Wilson [1] discusses digital storage for oscilloscopic display of transient signals; Ramsay [2] shows how this data storage furnished input for further computer processing. Usher [3] describes the general problem of signal conditioning for digital use. The most important digital development for the vibration engineer has been the Fast Fourier Transform (FFT). Lang [4] discusses its role in impact analysis; Potter [5] shows how FFT can be used for structural analysis. These five articles--written by engineers working for equipment manufacturers--do not adequately discuss limitations.

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Some limitations are inherent to the measuring technique [6-8]; others have to do with the instrument itself [9, 10]. Digital methods can also be used to control vibration testing [11, 12].

Roberts and Charlton [13] and Lowry [14] show how commerically available equipment can be used to obtain analog rather than digital correlations. The interpretation [15] and storage [16] of analog data are still of interest. Modal excitation of real damped structures requires careful attention to amplitude ratios and phasing of multiple shakers. The problem of shakers has been discussed many times since Fraejis de Veubeke's original paper in 1946 and is still of concern [17]. There is also interest in environmental vibration testing [18, 19].

The determination of system parameters from measured information [20, 21] furnishes the input necessary for digital analysis of dynamic response. Such analysis is particularly important in helicopter dynamics; the U.S. Army Laboratories have sponsored a substantial study project the results of which have been summarized [22].

INSTRUMENTATION

A survey of currently available accelerometers and vibration exciters has recently been issued [23]. The Australian National Standards Laboratory has made a study of calibration techniques [24-26]. Kenner [27] shows that impact force is accurately measured by a crystal transducer even if the load is not uniformly distributed. New methods that have been proposed for measuring impact [28], flexure [29], angular velocity [30], and acceleration [31] may prove useful for specialized applications. A complicated optical method [32] does not load light structures. A guide to the selection of vibration test equipment is available [33]. Inertial excitation [34] is useful for finding the dynamic response of buildings, nuclear reactors, and other large heavy structures.

Optical holography is widely used in machinery diagnosis [35-37] and is measuring mode shapes of plates [38-41], cylinders [42], cylindrical shells [43, 44], and rotating propellor blades [45]. Optical holography can also be used to measure shock waves in rotating machinery [46, 47]. Another optical method uses moiré fringes [48-51]. Dynamic photoelasticity is particularly useful for wave propagation studies [51-54].

MATERIAL PROPERTIES

Instrumentation for determining the dynamic properties of materials is a difficult problem. The torsion pendulum is the traditional system [55-57] and is still useful for low frequencies. Intermediate frequency measurements (1 to 1,000 Hz) can be made directly [58, 59], in flexure [60, 61], or on a shaker [20]. Pulse techniques can be used at higher frequencies [62, 63]. The split Hopkinson bar is a useful technique for measuring the dynamic stress strain curve at strain rates from 10^2 to 10^4 per second [64-66].

Acoustic holography is a recent technique developed for ultrasonic nondestructive testing. A textbook has been published [67] as well as a bibliography of federally funded research [68]. Acoustic holography is particularly useful for checking lack of bond [69] and flaws in welds and thick-walled pressure vessels [70].

DIAGNOSTICS

Vibration monitoring has long been used to detect unbalance or bearing wear. About ten years ago, the analog spectrum analyzer made spectral monitoring useful as Mechanical Signature Analysis [71, 72]. It is still being studied [73-77]; digital correlation techniques should make it even more sensitive for detecting wear and mechanical deterioration. More papers on systems used in specific industries would be useful [80]. Methods for finding mode shapes and frequencies [81, 82] and dynamic response of nuclear power plants [83, 84] are in widespread use. New plants are being equipped with instruments to determine the effects of earthquakes [85, 86]. Shock and vibration engineers, along with everyone else, must pay increasing attention to cost-effectiveness; I have found only one report of a study of cost-optimization of vibration instrumentation [87].

CODA

Many of the topics mentioned above should be reviewed; certainly dynamic photoelasticity, moiré techniques, digital spectral analysis, acoustic holography, and dynamic properties of material should be reviewed. Current practice in determining dynamic system parameters from measured information should also be reviewed. Transducers used in vibration and shock instrumentation are based on the same principles as those used ten years ago. The problems remain about the same. Although design and material improvements have been made, the major advance has been in electronics, high gain operational amplifiers, integrated circuits, wide range logarithmic amplifiers, and hard wired FFD digital minicomputers. The end of the digital computer revolution is not yet in sight; small, inexpensive computers will certainly continue to influence vibration measurement techniques.

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BOOK REVIEWS

VIBRATION AND NOISE IN MOTOR VEHICLES

Published by the Institution of Mechanical Engineers, 1972

This volume contains the 17 papers and discussions of a 1971 symposium arranged by the Automobile Division of the Institution of Mechanical Engineers (IME) and the Advanced School of Automotive Studies.

The book reflects the usual high standards of the IME. The contents should be of interest to researchers, engineering practitioners, and students particularly motor vehicle vibration analysts and acousticians. Most of the papers were presented by either academicians (or researchers) and industrial practitioners. The papers comprise research findings and tutorial expositions. The latter include descriptions of analytical and laboratory methods either in use or under development. The contents cover noise and vibration isolation, vibratory response of mechanical components used in motor vehicles, and the analysis and design of motor vehicle systems so as to reduce levels of vibratory response.

With respect to noise and vibration isolation, Davies and Alfredson demonstrate that a linear acoustic model adequately describes exhaust systems and can be used to design silencers (i.e., mufflers) for internal combustion engines. Bolton-Knight showed, by analysis and experiment, that engine mounting locations and configurations can be so selected as to reduce the noise and vibration levels in the passenger compartment of motor vehicles. Puydak and his associates reviewed the basic principles involved in selecting and using elastomers for dynamic mounting systems; they applied these principles to the engine mount selection problem. Waters discussed the sources and characteristics of commercial vehicle noise and concluded that noise shields reduce environmental engine noise. Jennequin was concerned with noise within the passenger compartment; he concluded that it is feasible to compute the modal response of the enclosed air volume in order to identify the interior panels responsible for inducing the noise. Fontanet outlined methods that have been used to reduce noise generated by second-order reciprocating forces of a four-cylinder, in-line engine.

One vibratory response of motor vehicle components -- the mechanism of "brake squeal" -- was addressed by Spurr, who argued that squeal arises from the coupling of vibrations within the brake assembly. Earles and Soar pointed out that a generally acceptable solution for solving the problem of squeal has not yet been found. Crankshaft vibrations are under considerably better control, however, as was shown by Hodgetts with regard to an internal combustion engine. Sykes and Wyman described the use of receptance methods for calculating the vibratory responses of typical drivelines. The control of noise generated by gears in automotive transmissions was reviewed by Ill. Egbuson et al examined the vibratory behavior of the rear-axle assembly commonly employed in motor cars.

The tendency in the remaining papers was to regard the motor vehicle as a complete system. Barson and Dodd presented experimental results of tires on irregular surfaces. Mills and Dunn, who were concerned primarily with the tire as an isolation element between vibration source and occupant, measured the mechanical impedance/mobility of a variety of tires and showed that resonant frequencies and mode shapes vary with tire design. Phillips also considered the transmissibility of road noise. Instrumentation and test techniques for solving noise, vibration, and harshness problems were described by Timms and O'Brien from the standpoint of the development process facing the manufacturer. Butkunas stressed the need for relating laboratory results with those obtained on the road. He described two experimental methods that can be used on the road to obtain the vehicle transfer function and averaged instantaneous mode shapes.

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RELIABILITY DESIGN FOR VIBROACOUSTIC ENVIRONMENTS
Edited by: D.D. Kana and T.G. Butler
ASME Publication AMD - Volume 9 (1974)

In this book reliability is shown to be a statistical parameter. The foreword states: "The purpose of this (volume) is to present some fundamentals and current developments in the application of reliability concepts to the prediction of successful functioning of hardware and structures in vibration and acoustic environments." Reliability has become a valuable tool in equipment design for seismic environments and rotating machinery.

This little volume consists of nine papers. The first, which deals primarily with mechanical reliability theory, contains approaches to the reliability of mechanical components and information about cumulative fatigue reliability. The Goodman diagram, Von Mise's equations of stress, and the normal distribution curve are applied to fatigue loading of materials. The reviewer would have liked a discussion of the application of fatigue under random environmental conditions.

The second paper discusses the unpredictability of materials and the properties and geometry of components and their influence upon performance of the entire system. The authors propose a nine point program for developing design tolerances.

The next two papers describe reliability design in shipbuilding and seismic reliability of equipment design. The latter was shown to be necessary after the 1971 San Fernando Earthquake. The authors suggest design criteria and spectra for testing in a seismic environment and methods for reducing the effect on equipment of high acceleration. An outline for simulating a model of a lifeline system of a large metropolitan area is included.

The fifth paper considers data analysis of random signals, the meaning of power spectral density, coherence function, AD conversion, and transfer function. An example of coherence behavior is given. The author has published an in-depth study entitled "Digital Time Series Analysis."

The sixth paper considers recent developments in vibration equivalence concepts. The application of Miner's rule is stressed and applied to a composite equivalence profile in order to review the design of a product. Each potential damage-producing process and its characteristics are identified. The reviewer was disappointed that random-sine equivalence and its application to design studies were not considered in any detail.

The seventh paper describes accelerated reliability testing of missile components under vibroacoustic environments. Actual missile components were tested in a simulated environment. The statistical evaluation of the breakdown of mechanical and electrical components should serve as an eye opener to those number-conscious designers with little conception of physical reality.

The final papers consider the application of field vibration data in laboratory tests of transported vehicles and in space payload dynamic testing.

The book is a good compendium of reliability testing in vibroacoustic environments. In my opinion information about reliability in the design of bridges and buildings subjected to wind loadings should have been included.

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REVIEWS OF MEETINGS

47TH SHOCK AND VIBRATION SYMPOSIUM

19-21 October 1976
Albuquerque Convention Center
Albuquerque, New Mexico

The 47th Shock and Vibration Symposium, sponsored by the Shock and Vibration Information Center (SVIC), was held in Albuquerque, New Mexico, in October. It was hosted by the Defense Nuclear Agency (DNA), Washington, D.C. and the Field Command Defense Nuclear Agency with the cooperation of the Air Force Weapons Laboratory, Kirtland AFB, New Mexico. The formal technical program contained more than 80 papers (see Vol. 8, No. 9, of the DIGEST for the complete program; paper summaries are available from the SVIC); a session of short reports of work in progress; and panel sessions on dynamic effects on reliability, modal testing and analysis, and survivability and vulnerability of military systems. Henry Pusey, Director of the SVIC, the members of the SVIC staff, and the program committee are to be congratulated for assembling an interesting program. Among the more than 350 participants were representatives of the federal government, industry, and the teaching profession. The attendees participated in both the formal and informal technical programs, thereby effecting a meaningful transfer of shock and vibration technology.

The Opening Session

The opening session was chaired by Dr. Eugene Sevin, Chief of Strategic Structures Division, DNA. Symposium participants were welcomed on behalf of the DNA by General Thomas E. Lacy. Colonel Lawrence Epley greeted the Symposium on behalf of the Air Force, and Mayor Harry Kinney did the same on behalf of the City of Albuquerque. General Lacy described the formation and scope of DNA and noted that, like the SVIC, DNA will soon celebrate its 30th anniversary. Colonel Epley stated the mission of the Air Force Weapons Laboratory in peace time: to prepare to fly and fight. He cited new programs involving missiles and lasers. Mayor Kinney, a former engineer with Sandia Laboratories, described the growth and rebuilding of Albuquerque.

The keynote speaker, Dr. Hua Lin, is Assistant Director (Offensive Systems), Office Director of Defense Research and Engineering, Washington, D.C.. During his talk on "Shock and Vibration Considerations in Weapon System Acquisition," Dr. Lin discussed weapon systems development, the role of vibrations in repairs for the B1 bomber, and the effect of shock and vibration considerations on the structural integrity and acoustic radiation of submarines. He noted that shock and vibration are often dealt with as necessary evils and that their importance is often recognized only after a program is in trouble. Unnessarily high costs for corrective measures result. Dr. Lin spoke of the concern of the Department of Defense with successful performance of a mission, the capability to execute the mission at the desired time, and the affordability of the system.

The thrust of the talk was the desirability to avoid the costly pitfalls of weapon systems procurements. These pitfalls include unrealistic shock and vibration specifications, design trade offs (i.e., the exlusion of effective shock and vibration efforts), and difficulty in verifying performance. Unrealistic specifications are the most common problem. Dr. Lin cited unquestioned use of MIL-STD-810B and argued that undue conservatism must be avoided. Determination of realistic specifications requires better prediction techniques: probabilistic approaches would be useful, and early conceptual tests would allow the identification of limits to the problem. In Dr. Lin's opinion, shock and vibration efforts should begin during the design trade-off process, in which reasonable specifications are used to avoid later fix-up costs. In his concluding remarks Dr. Lin again stressed affordability of weapon systems, trade-off studies early in the design process, less conservative design, and reasonable specifications. He stressed the value of the Shock and Vibration Symposium as a forum for personal contact and discussion of technical problems

Three invited speakers were part of the opening session. Major Donald Gage of the Space and Missile Systems Organization discussed blast, shock, and vibration design considerations for Missile X. Major Gage described the character and objective of Missile X - an underground mobile missile - as well as hardening and isolation mounting systems applied to the missile.

Mr. Noah J. Hurst of the Ballistic Missile Systems Defense Command talked about nuclear hardness in a missile defense system for now and for the future. Mr. Thomas Kennedy of DNA gave an excellent review on instrumentation technology -- which includes, according to his definition, the entire measurement system. He discussed phenomena measurement, data transmission, recording, data reduction, and reporting. Among the factors which he feels require attention are higher frequency and level measurement capability, increased linearity range, and phase measurements. Mr. Kennedy summarized recent developments: data processing at the transducers, fiber optics for transmission, multiplexing of data, and telemetry. He appeared interested in direct digital recording of data -- a feat that will require development of digital transducers.

The Technical Program

The technical program contained the following formal sessions: shock testing and analysis, isolation and damping, vibration testing, vibration analysis, instrumentation and data analysis, systems applications, and structural dynamics. Panel session topics included dynamics effects on reliability and survivability and vulnerability of military systems. A planning session for a seminar on modal testing and analysis was also held. An interesting session on short reports of work in progress included elastomeric mount characterization, impact testing, vibration testing, vibration analysis of shipboard and missile systems, and a computational model for piezoelectric materials in transducers.

The Symposium is the only forum for discussion of shock technology. Many of the papers pertained to the application of analytic and testing techniques to military and industrial problems. New and practical means for seismic and weapon effects testing include waveform reproduction on electrodynamic shakers and hydraulic actuators. Scaling of strong shock Hugoniots and shock spectra and responses using a pocket calculator were of interest.

Isolation technology used in the SAFEGUARD System and elastomeric element design were part of the session on isolation and damping. A new technological development in damping was described: the characterization of bulk cushion material for its viscoelastic and thermal properties. Reports were also given on the use of damping in the reduction of vibration and stress in aircraft. Testing techniques, fixture design, and new instrumentation were discussed during the vibration testing session. In addition case histories on vibration testing of hardware were given. The vibration analysis session included reports of applications of vibration theory to the solution of cable, plate, panel, and structural problems. A session on structural dynamics contained descriptions of unusual problems on composite-material flywheels for energy storage, pipeline response, and gas dynamic laser mounting forces.

New measurement equipment and techniques were part of the Instrumentation and Data Analysis session. Measurement of angular vibration using conventional accelerometers should prove to be valuable for many engineers. A low power laser and light-sensitive diode for measuring displacement data may eventually have wide application.

A session on systems identification and computer applications was concerned with the application of known techniques to existing problems and with the development of new techniques.

The Symposium papers will be reviewed for the quality of technical content and presentation. Selected papers will be published in the 47th Shock and Vibration Bulletin - available from the Shock and Vibration Information Center, Washington D.C..

The Ladies Program

In conjunction with the Symposium, an extensive ladies program, planned by Mrs. Pusey and Mrs. McWhirter and capably directed by Barbara Reeback of Bienvenidos Tour Gals, was given. More than 25 women renewed acquaintances during a trip to Española and environs for shopping -- and a delicious lunch at Rancho de Chimayo; a visit to old Santa Fe, including The Fenn Gallery; and a fascinating tour of the Acoma Pueblo. The Symposium activities concluded with a tour of Sandia Laboratories on Friday morning.

SHORT COURSES

JANUARY

INTRODUCTORY COMPUTER METHODS AND APPLICATIONS

Dates: January 11 - 14, 1977
Place: The University of Texas at Austin
Objective: This four-day course will introduce participants to problem formulation and problem solving in the area of structural dynamics. Emphasis will be placed on mathematical modeling of structures and on numerical methods for solving free vibration and dynamic response problems. Special sessions will treat applications of special interest to aerospace, civil, and mechanical engineers. Participants completing this course should have some knowledge of numerical techniques used in current computer programs having structural dynamics capability.

Contact: Engineering Institutes, College of Engineering, Cockrell Hall 2.102, The University of Texas at Austin, Texas 78712

DIGITAL SIGNAL PROCESSING

Dates: January 18 - 20, 1977
Place: Cincinnati, Ohio
Objective: Theory and applications of Fast Fourier Transform (FFT) hardware will be discussed. The meaning and uses of Fourier transforms, transfer functions, frequency response functions and convolution in the frequency and time domains will be covered. A discussion on architectural and operational concepts of a dual-channel digital signal processor is included in the program. Finally, applications of a dual-channel FFT processor to different engineering and signal analysis problems will be covered.

Contact: Mr. Bob Kiefer, Spectral Dynamics Corp. of San Diego, P.O. Box 671, San Diego, CA 92112 Tele. (714) 565-8211

PREVENTIVE MAINTENANCE AND FAULT DIAGNOSIS

Dates: January 31, February 1 & 2, 1977
Place: University of Houston Hotel
Objective: This seminar is devoted to the understanding and application of vibration technology to machinery preventive maintenance programs and fault diagnosis problems. Basic and advanced techniques with illustrative case histories and demonstrations will be discussed by industrial experts and consultants. Topics to be covered in the seminar include development of preventive maintenance programs; measurements, analysis, and data reduction, shock pulse techniques for bearing analysis; computer monitoring; and acoustic techniques. An instrumentation show will be held in conjunction with this seminar.

Contact: Dr. R. L. Eshleman, Vibration Institute, Suite 206, 101 W. 55th St., Clarendon Hills, IL 60514 Tele. (312) 654-2254/654-2053

FEBRUARY

INTRODUCTION TO VIBRATION AND SHOCK TESTING, MEASUREMENT, ANALYSIS AND CALIBRATION

Dates: February 14 - 18, 1977
Place: Santa Barbara, California
Objective: This course will benefit plant engineers and maintenance personnel responsible for on-line condition analysis of rotating machinery. Electronic techniques for analysis of vibration and sound signatures in terms of specific machinery faults will be discussed. This course will concentrate upon equipments and techniques rather than upon theory.

Contact: Mr. W. Tustin, Tustin Institute of Technology, Inc., 22 E. Los Olivos St., Santa Barbara, CA 93105 Tele. (805) 963-1124

MACHINERY VIBRATION ANALYSIS

Dates: February 15 - 17, 1977

Place: Lanham, Maryland

Objective: This course will cover such areas as fundamentals of vibration, vibration and analysis, transducer concepts, machine protection systems, analyzing vibration to predict failures, reducing unbalance forces, reducing misalignment forces, interpreting vibration signatures, improving analysis capability, and managing vibration data by computer.

Contact: Mr. Bob Kiefer, Spectral Dynamics Corp. of San Diego, P.O. Box 671, San Diego, CA 92112
Tele. (714) 565-8211

MODELING IN ENGINEERING DYNAMICS

Dates: February 28 - March 4, 1977

Place: San Antonio, Texas

Objective: This course is recommended for prospective students who have a bachelor's degree in some field of engineering, physics, or mathematics. The intent of this course is to introduce and illustrate to engineers, physicists, and scientists investigating transient phenomena the powerful tool of model analysis, and although the course is directed toward experienced personnel, a newcomer to the fields of survivability analysis, terminal ballistics effects, safety engineering, engineering dynamics, etc. can keep pace by diligently applying himself.

Contact: Mr. Peter S. Westine, Southwest Research Institute, P.O. Box 28510, San Antonio, TX 78284

MARCH

CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates: March 7 - 11, 1977

Place: UCLA

Objective: This course covers the latest practical techniques of correlation and coherence analysis--ordinary, multiple and partial--for solving acoustics and vibration problems in physical systems.

Contact: Continuing Education in Engineering and Mathematics, Short Courses, 6266 Boelter Hall, UCLA Extension, Los Angeles, CA 90024
Tele. (213) 825-1047

MEASUREMENT SYSTEMS ENGINEERING

Dates: March 14 - 19, 1977

Place: Phoenix, Arizona

Objective: Program emphasis is on how to obtain valid, cost-effective data in the field and in the laboratory during the next decade through increased productivity of data acquisition systems and groups. The latest developments in the new Unified Approach to the Engineering of Measuring Systems to achieve these aims, will be presented.

Contact: Prof. P. Stein, Short Course Director, 5602 East Monte Rosa, Phoenix, AZ 85018
Tele: (602) 945-4603/965-3124

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

ASTM COMMITTEE ON ENVIRONMENTAL ACOUSTICS APPROVES NEW STANDARDS

Two proposed new standards were approved for submission to ASTM letter ballot during the meetings of American Society for Testing and Materials (ASTM) Committee E-33 on Environmental Acoustics in Denver on October 11-13, 1976.

A proposed Method for Laboratory Measurement of the Noise Reduction of Sound Isolating Enclosures describes reverberation room measurement of the noise reduction of audiometric rooms, personnel booths, and other sound isolating enclosures.

A proposed Tentative Recommended Practice for Measuring a Single-Number Rating of the Airborne Sound Isolation in Multifamily Dwellings Suitable for Use in Building Specifications describes uniform procedures for determining the A-weighted noise reduction between neighboring (usually adjacent) rooms in a building. This recommended practice is intended for use by building code writers and others concerned with sound isolation between dwelling units, hotel and motel rooms, hospital rooms, and small offices.

The next meetings of Committee E-33 will be on April 11-13, 1977 in Bethesda, MD. Meeting details can be obtained from the Committee Secretary, Charles W. Rodman, Battelle Memorial Institute, 505 King Ave., Columbus, OH 43201 (Tele: 614-424-6424).

FIFTEENTH MIDWESTERN MECHANICS CONFERENCE

The Fifteenth Midwestern Mechanics Conference will be held March 23 - 25, 1977, at the University of Illinois at Chicago Circle. Members of the mechanics community throughout the United States and Canada are invited to join as participants. Unlike those of previous Midwestern Mechanics Conferences, the Proceedings of this conference will contain only the abstracts of papers. Full publication elsewhere in professional journals is permitted and encouraged.

For further information, contact Prof. T.C.T. Ting, Dept. of Materials Engineering, Univ. of Illinois at Chicago Circle, Box 4348, Chicago, IL 60680

TWENTY-THIRD INTERNATIONAL INSTRUMENTATION SYMPOSIUM

This will be the fourth in a series of symposia jointly sponsored by the Aerospace Industries and Test Measurement Divisions of the Instrument Society of America. The previous meetings have established this symposium as the outstanding forum for presentation of original work in aerospace and test measurement instrumentation. Papers will be presented which cover advances in, or new applications of, instrumentation devices, systems, or techniques in the following fields:

MEASUREMENTS: Strain; Motion; Flow; Pressure; Thermal; Acoustics, Shock and Vibration

INSTRUMENTATION TECHNIQUES & HARDWARE: NDT & Acoustic Emission; Analog Signal Conditioning; Microprocessors & Minicomputers; Electro-Optic/Photographic

APPLICATIONS: Aircraft; Space & Reentry Vehicles; Oceanography, Land Vehicles; Machinery; Nuclear Reactors; Automation

TEST CONTROL & DATA ANALYSIS: Real Time Display & Control, Microprocessor, Minicomputer and Calculator Applications

The symposium will be held at the Dunes Hotel in Las Vegas, Nevada on May 1 through 5, 1977. For additional information, contact: Mr. Phillip Legendre, Aerospace Corp., 2350 East El Segundo Blvd., El Segundo, CA 90245

ABSTRACT CATEGORIES

ANALYSIS AND DESIGN

Analogs and Analog Computation
Analytical Methods
Dynamic Programming
Impedance Methods
Integral Transforms
Nonlinear Analysis
Numerical Analysis
Optimization Techniques
Perturbation Methods
Stability Analysis
Statistical Methods
Variational Methods
Finite Element Modeling
Modeling
Digital Simulation
Parameter Identification
Design Information
Design Techniques
Criteria, Standards, and Specifications
Surveys
Tutorial
Mode Synthesis

COMPUTER PROGRAMS

General
Natural Frequency
Random Response
Stability
Steady State Response
Transient Response

ENVIRONMENTS

Acoustic
Periodic
Random
Seismic
Shock
General Weapon
Transportation

PHENOMENOLOGY

Composite
Damping
Elastic
Fatigue
Fluid
Inelastic
Soil
Thermoelastic
Viscoelastic

EXPERIMENTATION

Balancing
Data Reduction
Diagnostics
Equipment
Experiment Design
Facilities
Instrumentation
Procedures
Scaling and Modeling
Simulators
Specifications
Techniques
Holography

COMPONENTS

Absorbers
Shafts
Beams, Strings, Rods
Bearings
Blades
Columns
Controls
Cylinders
Ducts
Frames
Gears
Isolators
Linkages
Mechanical
Membranes, Films, and Webs
Panels
Pipes and Tubes
Plates and Shells
Rings
Springs
Structural

SYSTEMS

Absorber
Acoustic Isolation
Noise Reduction
Active Isolation
Aircraft
Artillery
Bioengineering
Bridges
Building
Cabinets
Construction
Earth
Electrical
Foundations
Helicopters
Human
Isolation
Material Handling
Mechanical
Metal Working and Forming
Off-Road Vehicles
Optical
Package
Pressure Vessels
Pumps, Turbines, Fans, Compressors
Rail
Reactors
Reciprocating Machine
Road
Rotors
Satellite
Self-Excited
Ship
Spacecraft
Structural
Transmissions
Turbomachinery
Useful Application

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, Va., 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM). 313 N. Fir St., Ann Arbor, MI. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 1911)

76-1872

Application of an Extended Hamilton's Principle to Damped Discrete and Continuous Systems

M. Levinson
Dept. of Civil Engrg. and Engrg. Mechanics, McMaster Univ., Hamilton, Ontario, Canada L8S 4L7
Mech. Res. Comm., 3, pp 125-131 (1976) 10 refs
Sponsored by the National Res. Council of Canada

Key Words: Hamiltonian principle, Mechanical systems, Damped structures

This paper shows how an extended Hamilton's principle may be applied to a wide variety of dissipative mechanical systems including damped acoustic waves. Both linear and nonlinear problems may be treated in this manner. The value of the extended Hamilton's principle, motivated by the principle of virtual work, is that it provides a basis upon which Rayleigh-Ritz and variationally based finite element approximations can be made. The principle was originally formulated in order to study (nondissipative) nonconservative problems of elastic stability and it has been used as the basis of finite element studies.

INTEGRAL TRANSFORMS

(See No. 1888)

NUMERICAL ANALYSIS

76-1873

Normalized Frequencies and Deviations as Function of Coupling, Mass-Loading and Harmonic: Numerical Results for Lateral Excitation

A. Ballato
Army Electronics Command, Fort Monmouth, NJ
Rept. No. ECOM-4404, 160 pp (Apr 1976)
Availability: Paper copy available from CDR. U.S. Electronics Command, ATTN: DRSEL-TL-ML, Fort Monmouth, NJ 07703

Key Words: Piezoelectric transducers, Resonant frequency, Vibration frequencies

This report provides specific numerical results, in the form of data tables, obtained from the solution of the pertinent transcendental equations governing the vibration frequencies of mass-loaded piezoelectric plates, in the one-dimensional approximation. The tables refer to excitation of a single thickness plate mode by an electric field in the lateral direction. Resonance and antiresonance frequencies are given in normalized form, along with frequency deviations, as function of harmonic of operation, piezoelectric coupling factor, and amount of mass-loading.

OPTIMIZATION TECHNIQUES

(See No. 1958)

FINITE ELEMENT MODELING

(Also see No. 1990)

76-1874

Three-Dimensional Finite Element Analysis for High Velocity Impact

S.T.K. Chan, C.H. Lee and M.R. Brashears
Lockheed Missiles and Space Co., Res. and Engrg. Ctr., Huntsville, AL, Rept. No. NASA-CR-134933; LMSC-HREC-TR-D390900, 160 pp (Aug 1975)
N76-21592

Key Words: Finite element technique, Impact response

A finite element algorithm for solving unsteady, three-dimensional high velocity impact problems is presented. A computer program was developed based on the Eulerian hydroelasto-viscoplastic formulation and the utilization of the theorem of weak solutions. The equations solved consist of conservation of mass, momentum, and energy, equation of state, and appropriate constitutive equations. The solution technique is a time-dependent finite element analysis utilizing three-dimensional isoparametric elements, in conjunction with a generalized two-step time integration scheme. The developed code was demonstrated by solving one-dimensional as well as three-dimensional impact problems for both the inviscid hydrodynamic model and the hydroelasto-viscoplastic model.

76-1875

Finite-Element Models for NUSC Vibration Experiments on Thin-Line Towed-Array Modules

C.S. Nichols, R.R. Smith and D. Barach

Naval Undersea Ctr., San Diego, CA., Rept. No. NUC-TP-496, 72 pp (Jan 1976)

AD-A022 662/1GA

Key Words: Sonar arrays, Towed bodies, Finite element technique, Mathematical models, Vibration response

Finite-element models were developed for thin-line towed-array modules. The modules that have been considered are a 15-ft hose strength member module, a 30-ft internal strength member module, and three different configurations for a 5-ft internal strength member module. The theoretical predictions of these models for impedance, transmissibility, longitudinal displacement and pressure level were compared to experimental measurements on these modules that were obtained at NUSC. Good agreement is obtained between the theoretical predictions and the experimental measurements. It is shown that the size of the spacer hole is an important parameter in determining the pressure level in an internal strength member module.

76-1876

Finite Element Analysis of Elastic-Plastic Wave Propagation Effects

H. Armen and H. Garnet

Materials and Structural Mechanics, Grumman Aerospace Corp., Bethpage, NY, 11714, Computers and Struc., 6 (1), pp 45-53 (Feb 1976) 15 figs, 20 refs

Key Words: Mathematical modeling, Finite element technique, Dynamic response, Wave propagation

The feasibility of dynamic analysis by means of the finite element method, in conjunction with direct time step integration procedures, has been demonstrated and documented in the literature. However, there appears to be some uncertainty concerning the validity of such analyses in cases involving wave propagation effects. It is the purpose of this paper to demonstrate that under appropriate conditions, nonlinear finite element analysis techniques, utilizing a variable time step integration procedure, may be applied to obtain a reliable description of the response of a body undergoing wave propagation effects.

MODELING

(See Nos. 1902, 1925, 1996)

DIGITAL SIMULATION

(See No. 2015)

PARAMETER IDENTIFICATION

(Also see Nos. 1965, 1966, 2011)

76-1877

Distributed System Identification: A Green's Function Approach

G.R. Spalding

Dept. of Engrg., Wright State Univ., Dayton, OH J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 146-151 (June 1976) 8 refs

Key Words: System identification, Continuous parameter method, Green function

A method is presented for identifying linear distributed parameter systems. Emphasis is placed on identification as a function of spatial coordinates by considering time-transformed, noise-free systems. Measurements of system response are combined with the Green's function method of analysis to obtain integral equations that can be solved for unknown spatial operators or coefficients. A discrete form of the theory is developed, utilizing Chebyshev polynomials. This allows prior estimates to be used to determine the number and location of spatial measurements.

76-1878

Frequency-Domain Synthesis of Optimal Inputs for Linear System Parameter Estimation

R.K. Mehra

Div. of Engrg. and Applied Physics, Harvard Univ., Cambridge, MA., J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 130-138 (June 1976) 1 fig, 24 refs

Key Words: Parameter identification, Dynamic systems, Structural synthesis, Frequency domain

This paper formulates the problem of estimating parameters in linear single-input multi-output dynamic systems as a *regression problem in frequency domain*. An expression for the information matrix is derived and its properties are studied. A frequency domain condition on the input for the nonsingularity of the information matrix is obtained.

DESIGN INFORMATION

(See No. 1991)

CRITERIA, STANDARDS, AND SPECIFICATIONS

(See No. 1975)

SURVEYS

76-1879

Structural Mechanics Software. Volume 1. March 1971-April 1975 (A Bibliography with Abstracts)

D.W. Grooms

NTIS, Springfield, VA, Rept. for Mar 1971 - Apr 1975, 190 pp (June 1976)
NTIS/PS-76/0436/6GA

Key Words: Bibliographies, Computer programs, Finite element techniques, Dynamic analysis

The use of computer programs in structural analysis-design problems are cited. Included are detailed analyses of structural problems, applied and theoretical, in many areas using finite elements and other numerical techniques. (This updated bibliography contains 185 abstracts, none of which are new entries to the previous edition.)

76-1880

Structural Mechanics Software. Volume 2. May 1975-May 1976 (A Bibliography with Abstracts)

D.W. Grooms

NTIS, Springfield, VA., Rept. for May 1975 - May 1976, 82 pp (June 1976)
(Supersedes NTIS/PS-74/428 and COM-74-10833)
NTIS/PS-76-0437/4GA

Key Words: Bibliographies, Computer programs

The use of computer programs in structural analysis-design problems are cited. Included are detailed analyses of structural problems -- applied and theoretical -- including stress analysis, vibration problems, shear stress analysis, deformation analysis and others. The major computer programs cited in this report are NASTRAN, EPSOLA, SUPER-SCEPTRE, and SINGER. (This updated bibliography contains 77 abstracts, all of which are new entries to the previous edition.)

76-1881

Highway Safety Structures (A Bibliography with Abstracts)

G.H. Adams

NTIS, Springfield, VA., 147 pp (Apr 1976)
NTIS/PS-76/0295/6GA

Key Words: Collision research (automotive), Highway transportation, Bibliography

Documentation is made of various structures and mechanical devices for promoting highway safety. Reports pertain to highway signs and displays, barriers, medians, breakaway poles and supports, crash cushions, parapets, guard rails, curbs, and fences. Discussions are presented of impact attenuators, diagrammatic signs, glare screens, high intensity sheeting, and arrester beds. Also noted are retroreflective color coded signs, median grates, louvered signs, redirecting curbs, and other installations. Some attention is given to tests and methodology. (Contains 142 abstracts)

76-1882

Acoustic Holography (Citations from the Engineering Index Data Base)

E.J. Lehmann

NTIS Springfield, VA., Rept. for 1970 - May 1976, 166 pp (June 1976) See also NTIS/PS-76/0440
NTIS/PS-76-0441/6GA

Key Words: Acoustic holography, Testing techniques, Bibliography

Worldwide research on acoustic holography is covered. Theory, uses, equipment design, and imaging techniques are presented. Most of the studies are general and not applied to a specific use of acoustic holography. However, there are citations which do discuss its use in medicine, nuclear reactors, and nondestructive testing. (Contains 161 abstracts)

76-1883

Acoustic Holography (Citations from the NTIS Data Base)

D.M. Craig and E.J. Lehmann

NTIS, Springfield, VA, Rept. for 1974 - May 1976 107 pp (June 1976) (Also see NTIS/PS-76/0441. Supersedes NTIS/PS-75/432 and COM-74-10871) NTIS/PS-76-0440/8GA

Key Words: Acoustic holography, Bibliographies

All aspects of acoustic holography are covered in this bibliography of Federally-funded research. Theory, equipment design, uses, and imaging techniques are presented. The applications include underwater and underground object locating, structural geology and tectonics, sonar imaging, non-destructive testing, antenna radiation patterns, nuclear reactor inspection, remote sensing, and a use in medical examinations. (This updated bibliography contains 102 abstracts, 38 of which are new entries to the previous edition.)

76-1884

Publications in Acoustics and Noise Control from the NASA Langley Research Center during 1940-1974

G.C. Smith and J.N. LaNeave

NASA Langley Res. Ctr., Langley Station, VA Rept. No. NASA-TM-X-72710, 71 pp (July 1975) N76-23942

Key Words: Noise control, Ducts, Blades, Aircraft noise, Sonic boom, Structural response, Human response

This document contains reference lists of published Langley Research Center papers in various areas of acoustics and noise control for the period 1940-1974. The research work was performed either in-house by the center staff or by other personnel supported entirely or in part by grants or contracts.

76-1885

Recent Advances in the Technology of Aircraft Noise Control

R.E. Pendley

Douglas Aircraft Co., Long Beach, CA., J. Aircraft, 13 (7), pp 513-519 (July 1976) 16 figs, 25 refs

Key Words: Aircraft noise, Noise reduction, Engine noise, Fans, Compressors, Turbines

Continuing research and development programs dealing with the technology of aircraft noise control have yielded recent significant advances. Certain noise sources about which little was known previously have become better understood. Concepts leading to more efficient noise suppression have been defined. This paper surveys recent results from a number of research and development programs active within industry and government. The paper discusses advances relating to the prediction and suppression of noise generated by engine components (fans, compressors, turbines, combustors, and jets). In addition, it discusses recent advances in the understanding of the noise generated by the aerodynamic flow over airframe components.

TUTORIAL

76-1886

Department of Transportation Surface Transportation Noise Abatement Programs

W.H. Close

Office of Noise Abatement, Dept. of Transportation, Washington, D.C., Noise Control Engr., 6 (2), pp 81-85 (Mar-Apr 1976)

Key Words: Noise reduction, Traffic noise

Several divisions of the Department of Transportation and their functions with respect to noise control are surveyed.

COMPUTER PROGRAMS

GENERAL

(Also see Nos. 1880, 1911, 1968)

76-1887

Computational Predictions of Shock Diffraction Loading on an S-280 Electrical Equipment Shelter

R.E. Lottero

Ballistic Research Labs., Aberdeen Proving Ground, MD., Rept. No. BRL-MR-2599, 39 pp (Mar 1976)

AD-A022 804/9GA

Key Words: Computer programs, Equipment response, Shock response

The Los Alamos Scientific Laboratory, under contract to the BRL, utilized a three-dimensional, transient, hydrodynamics computer program, BAAL, developed at LASL, to compute the diffraction loading versus time caused by a one-dimensional 34.475 kPa (5.0 psi) overpressure steady shock wave striking an S-280 Electrical Equipment Shelter.

76-1888

Community Noise Exposure Resulting from Aircraft Operations. Appendix: NOISEMAP Program Operator's Manual

N.H. Reddingius

Bolt Beranek and Newman, Inc., Canoga Park, CA Rept. No. BBN-2946, AMRL-TR-73-108-App, 29 pp (Feb 1976)

AD-A022 911/2GA

Key Words: Computer programs, Aircraft noise

This report delineates the program operator changes consistent with the additional developments made on the computer program described in AMRL-TR-73-109 (AD-A004 821). The added capabilities and improved diagnostics that form NOISEMAP 3.2 are discussed. NOISEMAP 3.2 is used Air Force-wide to compute community noise exposure from aircraft flying and ground runup operations for preparing/assessing candidate. Environmental Impact Statements and planning compatible land use in the vicinity of air installations.

76-1889

A Computer Program to Automate a Method for Predicting Acoustically Induced Vibration in Transport Aircraft

T. Harris

Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH., Rept. No. AFFDL-TM-75-111-FYS, 53 pp (Jan 1976) (Also see rept. dated Sept 1974, AD-A004 215)

AD-A022 571/4GA

Key Words: Transport aircraft, Vibration response, Acoustic excitation, Computer programs

The report presents a computer program which automates a vibration prediction method. Inputs to the program are estimates of fluctuating pressure levels in third-octave bands. These may be either sound pressure levels from the engines or the levels of aerodynamic flow turbulence. In addition, for new aircraft with structures which differ appreciably from contemporary transport designs, values of parameters which characterize the mass and rigidity ot the new structure may be input to the program.

NATURAL FREQUENCY

76-1890

Data Errors in the Computation of Free Motion

W. Gawronski

Technical Univ. of Gdansk, Inst. of Mechanics and Machine Design, 80-952 Gdansk, Poland, Computers and Struc., 6 (1), pp 17-27 (Feb 1976) 8 figs, 14 refs

Key Words: Error analysis, Natural frequencies, Mode shapes, Finite element technique, Computer programs

Input data in the computation of free motion (the inertia and stiffness matrices) contain some errors. These errors generate errors of output data (the natural frequency vector, the natural mode vectors). In this paper the relatinships between errors of input and output data in the computation of free motion are derived. This analysis is applied to the finite element method. The paper presents program ERROR, which computes the errors of the natural frequencies created by the inertia matrix errors. An example of the influence of the errors of the mass and of the mass moment of inertia on the natural frequencies of a ship hull is presented.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 1882, 1883, 1888, 1906, 1941, 1950, 1964, 1977, 1978, 1979, 1982, 1998)

76-1891

Fluid Mechanical Model of the Acoustic Impedance of Small Orifices

A.S. Hersh and T. Rogers

Hersh Acoustical Engineering, Chatsworth, CA. Rept. No. NASA-CR-2682, 57 pp (May 1976) N76-23947

Key Words: Holes, Acoustic impedance

A fluid mechanical model of the acoustic behavior of small orifices is presented which predicts orifice resistance and reactance as a function of incident sound pressure level, frequency, and orifice geometry. Agreement between predicted and measured values is excellent.

76-1892

Sonic Boom Propagation at Low Supersonic Speeds

N.W. Page

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/A-143, 37 pp (May 1975) N76-21203

Key Words: Sonic boom, Noise generation, Sound waves, Wave propagation

Atmospheric and flight conditions necessary to cause refraction of ray paths sufficient to reverse their vertical direction are examined. Analytical solutions were obtained for the height for vertical reversal of ray paths emanating from an aircraft flying at Mach numbers between 1 and 1.15 in a standard atmosphere with horizontal winds varying linearly with altitude. Both the height for vertical reversal of ray paths and ray path curvature were found to depend on a single non-dimensional refraction parameter which expresses the relative importance of refraction caused by vertical gradients of wind and temperature.

76-1893

Study of Community Noise Complaints Caused by Electric Power Plant Operations

R.M. Hoover

Bolt Beranek and Newman, Inc., 3344 Crossview, Houston, TX., Noise Control Engr., 6 (2), pp 74-80 (Mar-Apr 1976) 9 figs, 4 refs

Key Words: Electric power plants, Noise generation

The main results of a study of a number of documented cases of community complaints about noise due to power-plant operations are presented. The specific purpose of this study was to show the range of A-weighted sound levels at locations in the community where complaints had been made, to provide one guide for the evaluation of proposed design limits for the exterior noise of power-plant operations.

SEISMIC

(See Nos. 1905, 1991, 1992)

SHOCK

(Also see Nos. 1874, 1885, 1908, 1993)

76-1894

Design Study of a Suppressive Structure for a Melt Loading Operation

W.E. Baker, P.A. Cox, E.D. Esparza and P.S. Westline

Southwest Research Inst., San Antonio, TX., Rept. No. TR-9, EM-CR-76043, 74 pp (Dec 1975) (Also see rept. dated Nov. 1975, AD-A022 333) AD-A024 378/2GA

Key Words: Dynamic response, Blast loads, Explosion effects, Beams, Cylinders, Roofs

This report presents the results of a design study for a structure to suppress blast and fragment effects from detonation of a large quantity of Comp B explosive in a melt kettle. A number of design concepts were evaluated, and a specific configuration recommended. Relatively detailed design drawings were prepared.

TRANSPORTATION

(See No. 2001)

PHENOMENOLOGY

DAMPING

(Also see No. 2029)

76-1895

Study on Passive Nutation Dampers. Volume 1: Literature Survey and Analysis

L.J.Ancher, H. vdBrink,and A. Pouw

Space Div., Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost., Rept. No. FOK-RV-75-110-Vol-1; ESA-CR(P)-788-Vol-1, 218 pp (Dec 1975)

N76-22291

Key Words: Nutation dampers, Bibliographies, Spacecraft equipment

Passive type nutation dampers were analyzed for single spin satellites. A literature survey was carried out, and a list of criteria was compiled and used for a comparison of damper types. The following damper types were selected for further study since they are the most promising in terms of mass, performance, and reliability for future missions; pendulum with eddy current damping, tube with endpots damper, and partly filled annular damper. A mass-spring-dashpot damper was also studied. For each type, the damper-only equation was derived after decoupling the satellite motion and the damper motion. The coupled equations of motion were derived. The Routh-Hurwitz stability criterion was analyzed for the mass-spring-dashpot damper using linearized equations of motion. Existing methods of simulating the flight performance of the damper on the ground are outlined. For volumes 2 and 3, see ESR-96981 and ESR-96982.

76-1896

Study on Passive Nutation Dampers. Volume 2: Damper Selection and Dimensioning

L.J. Ancher, H. vdBrink and A. Pouw

Space Div., Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost, Rept. No. FOK-RV-75-110-Vol-2; ESA-CR(P)-788-Vol-2, 213 pp (Dec 1975)

N76-22292

Key Words: Nutation dampers, Bibliographies, Spacecraft equipment

Passive type nutation dampers were analyzed for single spin satellites. Types studied are: pendulum with eddy current damping, tube with endpots damper, and partly filled annular damper. A mass-spring-dashpot damper was also considered. A selection and dimensioning procedure of damper type is presented. The type of damper which should preferably be used in a given mission depends on both mission requirements and satellite parameters. A rigorous and a simplified dimensioning procedure is given for the pendulum and tube with endpots damper. The selection and dimensioning procedure is exemplified for three satellite missions defined by ESTEC. For volumes 1 and 3, see ESR-96980 and ESR-96982.

76-1897

Study on Passive Nutation Dampers. Volume 3: Appendices

L.J. Ancher, H. vdBrink and A. Pouw

Space Div., Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost, Rept. No. FOK-RV-74-110-Vol-3-APP; ESA-CR(P)-788-Vol-3-App, 128 pp (Dec 1975)

N76-22293

Key Words: Nutation dampers, Bibliographies, Spacecraft equipment

Passive type nutation dampers were analyzed for single spin satellites. Types studied are: pendulum with eddy current damping, tube with endpots damper, and partly filled annular damper. A mass-spring-dashpot damper was also considered. A literature matrix covering details of 108 publications studied is presented. Also included are mathematical details concerning mainly equations of motion of the various damper types. For volumes 1 and 2; see ESR-96980 and ESR-96981.

FLUID

(Also see Nos. 1921, 1938, 1939, 1940)

76-1898

Wave Forces on Models of Submerged Offshore Structures

P.E. Versowsky and J.B. Herbich

Coastal, Hydraulic and Ocean Engrg. Group, Texas A&M Univ., College Station, TX., Rept. No. TAMU-SG-74-215, COE-175, NOAA-76030304, 135 pp (Aug 1975)

PB-253 059/0GA

Key Words: Underwater structures, Offshore structures, Water waves, Model testing (testing of models)

The results of a model study of the forces caused by oscillatory waves on large rectangular tank-like submerged objects are presented. Three phases of the problem were examined: (1) description of the forces in terms of dimensionless parameters, (2) description of the effect of large wave heights which are of importance to the designer, and (3) the presentation of a format to be used in model studies on submerged structures. Theoretical studies of the problem have assumed wave heights to be small and the forces to be entirely inertial. However, of interest to the engineer are the forces caused by the larger waves generated by severe storms. In the model study the forces caused by the larger waves were determined and the effect of the water particle velocity in producing a drag force was examined. The relationships between the fluid particle displacement and the coefficients of mass and drag were evaluated.

76-1899

Cyclic Squeeze Films in Micropolar Fluid Lubricated Journal Bearings

J. Prakash and P. Sinha

Dept. of Machine Design, The Engrg. Research Foundation at the Technical Univ. of Norway, Trondheim, Norway, J. Lubric. Tech., Trans. ASME, 98 (3), pp 412-417 (July 1976) 10 figs, 14 refs

Key Words: Lubrication, Squeeze-film bearings, Journal bearings

The Reynolds equation for the general case of dynamic loading is derived for fluid suspensions, using the micropolar fluid theory. Detailed consideration is given to the dynamic behavior of squeeze films in journal bearings under a fluctuating load with no journal rotation. The characteristics of an infinitely long journal bearing under a cyclic sinusoidal load are shown in curve form, so as to elaborate the micropolar effects.

76-1900

Dynamic Analysis of Elastohydrodynamic Squeeze Films

S.M. Rohde, D. Whicker and A.L. Browne

Engrg. Mechanics Dept. Res. Labs., General Motors Corp., Warren, MI., J. Lubric. Tech., Trans. ASME, 98 (3), pp 401-408 (July 1976) 8 figs, 11 refs
ASME Paper No. 75-Lub-5

Key Words: Elastohydrodynamic properties, Lubrication, Transient response, Squeeze-film bearings

This paper contains an analysis of a class of elastohydrodynamic squeeze film problems. A transient analysis is presented. Thick films bounded by a finite rigid plate and a compliant half-space are considered. The effect of different approach constraints is explored, amoung these being constant and time varying load and constant and time varying center point pressure. The effect of different material models is also considered.

76-1901

Stability Analysis and Optimization of By-Pass Controlled Heat Exchanger with Boiling

J.S. Ansari

School of Automation, Indian Inst. of Science, Bangalore, India, J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 161-166 (June 1976) 3 figs, 7 refs

Key Words: Heat exchangers, Stability, Optimization, Mathematical models

A heat exchanger with boiling is considered. The final temperature of steam is controlled with the help of a controller which regulates the flow rate of by-pass water mixing with the outcoming steam. The simplest known mathematical model retaining the nonlinear and distributed parameter nature of the process is adopted. A known method of analysis, namely, Liapunov-Razumikhin theorem, is used to derive results on stability. An interesting feature of the system is that a positive feedback is required for stability. If the control is designed on the basis of minimization of the error in the final temperature alone, then the optimal control, requiring a negative feedback, leads to sustained oscillations in the intermediate variables, even when the output is steady. The analysis, therefore suggests that meaningful optimization must take into account fluctuations in intermediate variables in addition to the error. A derivative control is shown to improve the transient response.

SOIL

(Also see Nos. 1991, 2028)

76-1902

Dynamic Behavior of Partially Embedded Pile

M.A. Satter

Dept. of Mech. Engrg., Pahlavi Univ., Shiraz, Iran ASCE J. Geotech. Engr. Div., 102 (GT7), pp 775-785 (July 1976)
Paper No. 11265

Key Words: Pile structures, Pile driving, Interaction: soil-structure, Vibration response, Mathematical models

Vibrational behavior of a partially embedded pile has been studied theoretically and some of the results compared with available field data. A mathematical model incorporating "pile-soil interaction" for resonant pile driving has been proposed. Only the longitudinal mode of the pile has been considered, but the same theory may be modified slightly to predict torsional behavior as well. The model equation is solved through standard Fourier transform method. Certain simplification has been introduced to the solution to minimize computational effort while retaining good accuracy.

76-1903

Multiple Diffractions of Elastic Shear Waves by a Rigid Rectangular Foundation Embedded in an Elastic Half Space

M. Dravinski and S.A. Thau
Div. of Engrg. and Applied Science, California Inst. of Technology, Pasadena, CA., J. Appl. Mech., Trans. ASME, 43 (2), pp 295-299 (June 1976) 3 figs, 5 refs
Sponsored by the National Science Foundation

Key Words: Foundations, Interaction: soil-structure, Wave diffraction, Elastic waves

A rigid rectangular foundation, embedded in an elastic half space, is subjected to a plane, transient, horizontally polarized shear (SH) wave. Embedment depth of the foundation and the angle of the incidence of the plane wave are assumed to be arbitrary. The problem considered is of the antiplane-strain type. The Laplace and Kontorovich-Lebedev transforms are employed to derive the equation of motion for the foundation during the period of time required for an SH-wave to traverse the base width of the obstacle twice. Therefore this solution includes the process of multiple diffractions at the corners of the foundation.

76-1904

Multiple Diffractions of Elastic Waves by a Rigid Rectangular Foundation: Plane-Strain Model

M. Dravinski and S.A. Thau
Div. of Engrg. and Applied Science, California Inst. of Technology, Pasadena, CA., J. Appl. Mech., Trans, ASME, 43 (2), pp 291-294 (June 1976) 3 figs, 4 refs
Sponsored by the National Science Foundation

Key Words: Interaction: soil-structure, Foundations, Wave diffraction, Elastic waves

A rigid rectangular foundation embedded in an elastic half space moves in a direction perpendicular to the surface of the half space. The model under consideration is of the plane-strain type. By application of the Laplace, Fourier, and Kontorovich-Lebedev (K-L) transforms, the equation of motion for the foundation is derived. The transient response of the foundation is exact during the period of time required for a longitudinal wave to traverse the base of the foundation twice. Thus the process of multiple diffractions at the corners of the foundation is taken into account.

76-1905

Seismic Response and Liquefaction of Sands

W.D.L. Finn, P.M. Byrne and G.R. Martin
Dept. of Appl. Sci., Univ. of British Columbia, Vancouver, Canada, ASCE J. Geotech. Engr. Div., 102 (GT8), pp 841-856 (Aug 1976) 14 figs, 14 refs

Key Words: Sand, Seismic response

An effective stress analysis has been developed for determining the dynamic response of horizontal saturated sand deposits to earthquake motions consisting of vertically propagating shear waves. A hyperbolic stress-strain law is used for sands in shear and during the earthquake motions the modulus and damping properties of the sands are modified continuously for the effects of dynamic shear strains and pore-water pressures. The pore-water pressures are continuously updated using equations which relate pore-water pressures to dynamic shear strain history.

VISCOELASTIC

(Also see No. 2027)

76-1906

Vibration of Elastic Bodies with Small Viscoelastic Effects

S. Cerneau and E. Sanchez-Palencia
Ecole Normale Superieure de Fontenay-aux-Roses et Laboratoire de Mecanique Theorique, associe au C.N.R.S., J. Mecanique, 15 (2), pp 237-263 (1976) 20 refs
(In French)

Key Words: Acoustic properties, Viscoelasticity

The vibrations of elastic bodies whose equations of motion contain a small viscoelastic term are studied. By using the two-scale expansion method, the acoustic properties of the sound associated with the vibration are studied; as the oscillations decay, the sound tends to have a finite number of well-determined frequencies.

EXPERIMENTATION

DIAGNOSTICS

(Also see No. 1920)

76-1907

Proceedings of the 22d Meeting of the Mechanical Failures Prevention Group

T.R. Shives and W.A. Williard

Metallurgy Div., NASA, Goddard Space Flight Ctr., Greenbelt, MD., Rept. No. NASA-TM-X073005; PB-248254/5; CNBS-SP-436, 369 pp (Dec 1975) N76-22563

Key Words: Diagnostic techniques, Proceedings

These Proceedings consist of a group of nineteen submitted papers and discussions from the 22nd meeting of the Mechanical Failures Prevention Group which was held at the Grand Hotel in Anaheim, California on April 23-25, 1975. Failure detection, diagnosis, and prognosis represent the central theme of the Proceedings. Technology and techniques, ongoing diagnostic programs, and coming requirements in the field of diagnostics and preventive maintenance are discussed. In addition, several case histories are presented.

FACILITIES

76-1908

Exploding Wire Shock Test Facility

R.A. Boardman

Cushing Engrg. Inc., Northbrook, IL., Contract No. N00014-73-C-0402, 34 pp (April 15, 1976) AD-A024 924/3GA

Key Words: Shock tests, Test facilities, Underwater explosions

The Cushing Engineering Company Shock Test Facility has recently been assembled and demonstrated at Naval Research Laboratory, Washington, D.C. for the purpose of investigating and testing underwater explosion phenomena from a pure energy yield explosion source. In conjunction with these experiments, formulas were developed to accurately scale the data results from these tests to approximate large nuclear explosions. The attendant instrumentation for this facility, presently available, allows for the study of gas bubble dynamics, surface wave and shock wave propagation, rarefaction shock wave generated cavitation and column formation. The purpose of this document is to describe the aforementioned test facility equipment in regard to its construction, alignment and operational sequence.

76-1909

Note on Aero-Acoustic Measurements in Openjet Wind Tunnels

H.V. Fuchs

Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Berlin, W. Germany, Inst. fuer Turbulenzforschung, Rept. No. DLR-IB-357-74/4, 29 pp (1974) N76-22980

Key Words: Acoustic measurement, Wind tunnels

Sound measurements in a turbulent air flow are discussed. Problem areas include acoustic contamination, turbulent flow pressures, and probe flow interference. Possible probe developments for in-flow noise measurements are indicated, and a short survey of activities in pressure fluctuation and sound measurements inside airflows is given.

76-1910

The New Transonic and Supersonic Wind Tunnel of the Aerodynamic Institute

G. Freytag

Agnew Tech-Tran., Inc., Woodland Hills, CA., Rept. No. NASA-TT-F-16977, 18 pp (Apr 1976) (Engl. transl. from Rheinisch-Westfalische Tech. Hochschule, Abhandlungen (Aachen), no. 22, 1975, pp 233-238) N76-21222

Key Words: Wind tunnels

The available compressor installations restrict the use of the new wind tunnel to an intermittent operation schedule. Operational details are discussed, taking into account the employment of suction and pressure. The design of the wind tunnel is considered, giving attention to the Laval nozzle, the free jet chamber, the diffusor, and the transonic chamber.

76-1911
Sting Dynamics of Wind Tunnel Models
J.P. Billingsley
Arnold Engrg. Dev. Ctr., Arnold Air Force Station, TN., Rept. No. AEDC-TR-76-41, 65 pp (May 1976) (Prepared in cooperation with ARO, Inc., Tullahoma, TN, Rept. No. ARO-VKF-TR-75-150)
AD-A024 455/9GA

Key Words: Wind tunnel tests, Mountings, Oscillation, Computer programs

Wind tunnel model support stings can be subjected to transient aerodynamic and inertial loads which will create oscillatory translations and angular deflections. These transient oscillations always impair steady-state data accuracy and can be large enough to cause structural failure. The primary result of this investigation has been the formulation of a mathematical analysis for the dynamic response of sting-balance combinations subjected to arbitrary transient load inputs. The analysis also provides for sting rigid body motion so that model to tunnel injection and continuous sting rotation can be simulated. A computer program was written to numerically solve the sting-model-balance notion equations.

76-1912
Design and Preliminary Test Results at Mach 5 of an Axisymmetric Slotted Sound Shield
I.E. Beckwith, A.J. Spokowski, W.D. Harvey, and P.C. Stainback
NASA, Langley Res. Ctr., Langley Station, VA., Rept. No. NASA-TM-X-72679, 64 pp (June 1975)
N76-22217

Key Words: Acoustic absorption, Noise barriers, Wind tunnels

The basic theory and sound attenuation mechanisms, the design procedures, and preliminary experimental results are presented for a small axisymmetric sound shield for supersonic wind tunnels.

76-1913
Analysis of a Platform for Measuring Moments and Products of Inertia of Large Vehicles
D. Orne and T. Schmitz
Dept. of Mech. Engrg. Sciences, Wayne State Univ., Detroit, MI., J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 186-195 (June 1976), 10 figs, 5 refs

Key Words: Test facilities, Ground vehicles, System identification, Inertial forces, Vibratory techniques

A rigid platform symmetrically supported by four sloping cables is proposed for measuring the center-of-gravity coordinates and the moments and products of inertia of large vehicles such as buses, trucks, and trailers. In addition to a torsional degree-of-freedom, the system undergoes pitch and roll motions about axes through the system instantaneous center which lies directly below the center of the platform at the intersection of the cable lines-of-action under quiescent conditions. The natural frequencies and normal modes of the freely vibrating loaded platform are used as inputs to a linearized System Identification Algorithm for computing the inertia properties of the test vehicle. Hypothetical test data generated from the Free Vibration Analysis of a sample test configuration are used to evaluate the sensitivity of the System Identification Algorithm to inaccuracies in test data or to truncation errors in computation.

76-1914
Impact Dynamics Research Facility for Full-Scale Aircraft Crash Testing
V.L. Vaughan, Jr. and E. Alfaro-Bou
NASA, Langley Res. Ctr., Langley Station, VA, Rept. No. NASA-TN-D-8179; L-10514, 56 pp (Apr 1976)
N76-21173

Key Words: Test facilities, Aircraft, Crash research (aircraft)

An impact dynamics research facility (IDRF) was developed to crash test full-scale general aviation aircraft under free-flight test conditions. The aircraft are crashed into the impact surface as free bodies; a pendulum swing method is used to obtain desired flight paths and velocities. Flight paths up to -69 deg and aircraft velocities along the flight paths up to about 27.0 m/s can be obtained with a combination of swing-cable lengths and release heights made available by a large gantry. Seven twin engine, 2721-kg aircraft were successfully crash tested at the facility, and all systems functioned properly.

INSTRUMENTATION

(Also see Nos. 1873, 1887, 2031)

76-1915

New, Compact Instrument for Pulse-Echo-Overlap Measurements of Ultrasonic Wave Transit Times

E.P. Papadakis

Ford Motor Co., 24500 Glendale Ave., Detroit, MI 48239, Rev. Sci. Instr., 47 (7), pp 806-813 (July 1976) 8 figs, 16 refs

Key Words: Measuring instruments, Pulse test methods, Phase velocity

A new instrument is described which permits the travel time of ultrasonic waves to be measured accurately and conveniently by the pulse-echo-overlap method (PEO). The accuracy and versatility of the PEO method are reviewed, and optimal methods of preparing and interrogating samples are presented. Extensive data on a large blank of fused silica are presented. Longitudinal and shear wave velocities were calculated from the wave travel times through measured thicknesses, and the elastic moduli were subsequently calculated from the velocities and the measured density.

76-1916

Frequency Doubling--A New Approach to Vibrating Sample Magnetometers

C.N. Guy

Physics Dept., Imperial College, London SW7 2BZ, England, J. Phys. E., (Sci Instr.), 9 (6), pp 433-435 (June 1976) 4 figs, 6 refs

Key Words: Measuring instruments

It is shown that a general treatment of the properties of vibrating sample magnetometer pickup coils, leads to the possibility of induced signals at twice the frequency of sample vibration. Possible applications of this effect to two sample magnetometers and magnetic anisotropy measurements are discussed.

SIMULATORS

(See No. 1918)

TECHNIQUES

(Also see Nos. 1882, 1883, 1909, 1973, 2030)

76-1917

Dynamic Simulation in Windtunnels, Part 1

H. Hoenlinger and O. Sensburg

Messerschmitt-Boelkow-Blohm G.m.b.H., Unternehmensbereich Flugzeuge, Ottobrunn, W. Germany Rept. No. MBB-UFE-1180-0, 20 pp (Apr 1975) (Presented at the AGARD Flight Mech. Panel Symp. on Flight/Ground Testing Facilities Correlation, Valloire/Modane, France, 9-12 June 1975) N76-21192

Key Words: Flutter, Testing techniques, Wind tunnel tests, Aircraft wings, Wing stores

The techniques used to investigate flutter characteristics and flutter suppression systems are described. Two cases in which active flutter suppression was successfully applied are demonstrated. One case deals with the flutter of a wing with a store and the other with an empennage flutter case.

76-1918

Automated Dynamic Load Simulator--A Useful Tool in Evaluating Cranking System Design

S.M. Chohan

General Motors Corp., McCook, IL., ASME Paper No. 76-DE-13

Key Words: Automated testing, Testing techniques, Internal combustion engines

An automated dynamic load simulator was designed and constructed for laboratory endurance testing of internal combustion engine cranking system. This paper provides a description of the simulator from conceptual as well as hardware standpoints.

76-1919

Determination of the Dynamic Structural Response Characteristics of a Large Diesel Engine by Means of the Low Level Impedance Method

R.T.M. Yang

Delaval Turbine Inc., Oakland, CA., ASME Paper No. 76-DGP-9

Key Words: Diesel engines, Frequency response, Measurement techniques

This paper describes the combination physical and analytical approach used to determine the dynamic structural response of a large and complex structure like the diesel engines and auxiliaries. Due to the size and complexity of the diesel engine, the conventional shake table and modal analysis cannot accurately predict the dynamic characteristics of the system. This method enables accurate measurement of the frequency response at the various points of interest on the engine system. For nuclear standby power application, the diesel generator system will have to be seismically qualified for structural adequacy. The results of this test enable the necessary modifications and adjustments to the mathematical model, so that an accurate prediction of structural characteristics can be achieved.

76-1920

Comparison of Acoustic and Strain Gauge Techniques for Crack Closure Measurements

O. Buck, R.V. Inman, and J.D. Frandsen

Science Ctr., Rockwell Intl. Corp., Thousand Oaks, CA, Rept. No. NASA-CR-144968; SC5032.22FR, 40 pp (May 10, 1976)

N76-22581

Key Words: Diagnostic techniques, Acoustic techniques, Crack detection, Measuring techniques

A quantitative study on the systems performances of the COD gauge and the acoustic transmission techniques to elastic deformation of part-through crack and compact tension specimens has been conducted. It is shown that the two instruments measure two completely different quantities: The COD gauge yields information on the length change of the specimen whereas the acoustic technique is sensitive directly to the amount of contract area between two surfaces, interfering with the acoustic signal. In another series of experiments, compression tests on parts with specifically prepared surfaces were performed.

COMPONENTS

BEAMS, STRINGS, RODS

(Also see Nos. 1957, 2024)

76-1921

Random Response of Offshore Structures to Wave and Current Forces

S.C. Wu and C.C. Tung

Dept. of Civil Engrg., North Carolina State Univ., Raleigh, NC, Rept. No. UNC-SG-75-22, NOAA-76022006, 125 pp (Sept 1975)

PB-252 331/4GA

Key Words: Offshore structures, Towers, Dynamic response

Dynamic responses of offshore structures to random waves and steady current are examined. The structural response quantitities examined are the displacement, shear, and bending moment. The statistic sought is the peak response which is the quantity directly used in design considerations. Numerical results are obtained for four offshore towers, ranging in heights from 475 to 1075 feet, for various wave and current conditions. Results are presented graphically. It is shown that structural responses increase with increase in current speed but the effects of wave-current interactions are important only for tall slender structures. Also, the effects of current on structural response diminishes with increase in the strength of the waves.

76-1922

A Study of the Higher Modal Dynamic Plastic Response of Beams

N. Jones and T. Wierzbicki

Dept. of Ocean Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. 76-3, 40 pp (Apr 1976)

AD-A025 204/9GA

Key Words: Beams, Modal analysis

A theoretical and experimental investigation into the higher modal dynamic plastic response of fully clamped beams is reported herein. It is shown that the influence of geometry changes or finite-deflections is important. It appears that the higher modal response of beams is a more efficient means of absorbing a given magnitude of kinetic energy than a single modal response.

76-1923

Elastic-Plastic Response of 6061-T6 Aluminum Beams to Impulse Loads

M.J. Forrestal and D.L. Wesenberg
Simulation Research Dept., Sandia Laboratories, Albuquerque, NM, J. Appl. Mech., Trans. ASME, 43, (2), pp 259-262 (June 1976) 6 figs, 15 refs

Key Words: Beams, Pulse excitation, Shock excitation, Elastic plastic properties

The elastic-plastic response of 6061-T6 aluminum beams is examined experimentally and analytically. Simply supported beams are loaded with half-sine wave, short-duration magnetic pressure pulses and the response is monitored with a framing camera and strain gages. A closed-form elastic-plastic approximate theory for peak displacement is derived and compared with measurements and a numerical analysis. Measured displacement-time and strain-time histories are also compared with numerical predictions. Good agreement is shown between measurements and predictions.

76-1924

Dynamic Behavior of Ideal Fibre-Reinforced Rigid-Plastic Beams

N. Jones
Dept. of Ocean Engrg., Massachusetts Inst. of Technology, Cambridge, MA., J. Appl. Mech., Trans. ASME, 43 (2), pp 319-324 (June 1976) 4 figs, 14 refs

Key Words: Beams, Fiber composites, Anisotropy, Dynamic plasticity

Theoretical solutions are developed herein for the dynamic plastic structural response of some ideal fibre-reinforced (strongly anisotropic) beams with boundary conditions and external dynamic loadings which can be reproduced easily and reliably in a laboratory. The theoretical behavior of these beams is compared to the corresponding dynamic response of beams which are made from a rigid perfectly plastic isotropic material.

76-1925

A Lumped Mass Vibration Model of a Slender Latticed Cantilever

M.A. Parameswaran and K. Sukumaran
Mechanical Engrg. Dept., Indian Inst. of Technology, Madras, India, Computers and Struc., 6 (2), pp 107-109 (Apr 1976) 4 figs

Key Words: Cantilever beams, Normal modes, Lumped mass method, Mathematical models

A relatively simple numerical iterative procedure for estimating the normal modes of flexural vibrations of a slender, multipanel latticed cantilever, tapered or straight, is developed. The cantilever is reduced to a N mass system and the influence coefficients are derived with due consideration to the shear flow through the diagonal bracings. Experimental and computer results on a model are compared.

76-1926

Optimum Support Damping for a Vibrating Beam

J.C. Macbain and J. Genin
Air Force Aero Propulsion Lab., Wright-Patterson AFB, OH., Rept. No. AFAPL-TR-76-14, 16 pp (Feb 1976)
AD-A025 106/6GA

Key Words: Cantilever beams, Vibration damping, Supports, Mathematical models, Lumped mass models

A method for determining the optimum support damping of a flexibly supported cantilever beam using an analogous lumped mass model is described. The optimum system damping is determined as a function of rotational end-fixity of the cantilever support interface. The damping value based on the lumped mass model is found to be in good agreement with the damping value based on a mathematical model of a continuous cantilever beam.

76-1927

Added Mass and Damping of a Vibrating Rod in Confined Viscous Fluids

S.S. Chen, M.W. Wambsganss and J.A. Jendrzejczyk
Components Technology Div., Argonne National Lab., Argonne, IL., J. Appl. Mech., Trans. ASME, 43 (2), pp 325-329 (June 1976) 5 figs, 10 refs

Key Words: Cantilever rods, Submerged structures, Viscous damping

This paper presents an analytical and experimental study of a cylindrical rod vibrating in a viscous fluid enclosed by a rigid, concentric cylindrical shell. A closed-form solution for the added mass and damping coefficient is obtained and a series of experiments with cantilevered rods vibrating in various viscous fluids is performed. Experimental data and theoretical results are in good agreement.

76-1928

On Dualities in the Oscillations of Naturally Curved and Pretwisted Rods

B. Tabarrok and M. Farshad

Dept. of Mechanical Engrg., Univ. of Toronto, Toronto, Canada, Intl. J. Solids Struc., 12 (8), pp 601-609 (1976) 1 fig, 13 refs

Key Words: Curved rods, Initial deformation effects, Equations of motion

The pertinent equations of naturally curved and pretwisted rods, in the form of compatibility, equilibrium and constitutive relations are obtained under the assumptions of infinitesimal deformations and material isotropy. Then by forming the expressions for various energy terms, the equations of motion of the rod are obtained via Hamilton's principle and the complementary energy principle. On comparing these two forms of equations of motion, and the associated boundary conditions certain dualities are exposed. Finally the equations of some special rods, including the plane arch and the straight pretwisted rod, are examined.

76-1929

The Vibration of Cylinders

G.M.L. Gladwell

Solid Mech. Div., Faculty of Engineering, Univ. of Waterloo, Ontario, Canada, Shock and Vibration Digest, 8 (8), pp 13-24 (Aug 1976) 18 figs, 37 refs

Key Words: Cylinders, Rods, Free vibration, Reviews

This survey is concerned with the vibrations, mostly free undamped vibrations, of solid and hollow circular cylinders, not with cylindrical shells; the term 'rod' will be used to denote a solid circular cylinder. Shell theories will be considered only insofar as their ability to predict the vibrations of cylinders.

76-1930

Nonlinear Vibration of Cable Trusses

S.H. Mote

Ph.D. Thesis, Illinois Institute of Technology, 1975, 62 pp

UM 76-13, 165

Key Words: Cables (ropes), Suspension bridges, Nonlinear response

This study concerns the vibration of cable trusses consisting of a top cable curved up, a bottom cable curved down and connected with diagonal members. The system is nonlinear in that deformation can no longer be considered as small and must be taken into account in obtaining final deflections and stresses. In addition, the diagonals may be in and out of action during vibration.

76-1931

Phenomenological Investigation of the Resonance Effects on the Torsional Vibration Mode of a Cable Boom

D. Wyn-Robers and I. McVicar

Electronics and Space Systems Group, British Aircraft Corp., (Operating) Ltd., Bristol, England, Rept. No. ESS/SS-415; ESA-CR(P)-230, 141 pp (Dec 1972) N76-22551

Key Words: Cables (ropes), Spacecraft equipment, Equipment mounts, Torsional vibration

The purpose of the investigation was to examine the behavior of a variety of cable booms under the influence of mechanical and thermal excitation, for application to the GEOS satellite as supports for equipment sensors. The behavior of the cable under various conditions was investigated. Resonance modes were clearly identified with large amplitude magnification occurring for both torsion and lateral resonance conditions. Oscillating heating alone did not cause any movements of the cable even when induced in resonant frequencies. Reducing the tip inertia of the cable caused an expected increase in torsion resonance frequencies. A number of cases were highlighted where cross-coupling between lateral and torsion modes occurred.

BEARINGS

(Also see No. 1899)

76-1932

Bending Stresses in Spherically Hollow Ball Bearing and Fatigue Experiments

L.J. Nypan, H.H. Coe and R.J. Parker

California State Univ., Northridge, CA., J. Lubric. Tech., Trans. ASME, 98 (3), pp 472-475 (July 1976) 5 figs, 11 refs

ASME Paper No. 75-Lub-8

Key Words: Ball bearings, Fatigue tests

Spherically hollow balls of 21.7, 50.0 and 56.5 percent mass reduction have been operated in ball bearings and in a 5-ball fatigue tester with differing outcomes. Available theoretical and experimental treatments of stresses in spherically hollow balls are reviewed and compared. Bending stresses are estimated for these spherically hollow balls to better understand the differences in ball bearing and fatigue test experience.

76-1933

Prediction of Rolling Contact Fatigue Life in Contaminated Lubricant: Part II - Experimental

T.E. Tallian

Technology Services, SKF Industries, Inc., King of Prussia, PA., J. Lubric. Tech., Trans. ASME, 98 (3), pp 384-392 (July 1976) 11 figs, 16 refs

Sponsored by the U.S. Navy, Air Engineering Center, Philadelphia, PA

Key Words: Ball bearings, Lubrication, Fatigue life

In this second part of a two-part paper, experimental fatigue life data on ball bearings operated under different lubrication conditions are correlated to surface damage densities of life tested ball bearing inner rings, as determined by scanning electron microscopy. In Part I, five cases of a mathematical model for the prediction of fatigue life in contaminated bearings were presented. The models are fitted to the experimental data given in the present Part II. The correlation coefficient of experimental L_{10} life with model Case II predictions, based on observed defect densities, is of the order of 0.99 and highly significant for most test groups. One grease lubricated group requires fitting by model Case III. Predicted life dispersion exponents are too high compared to experiment. General data on lubricant contaminant densities show a sufficiency of particles to cause the observed surface damage, but tend to overpredict damage on the basis of the simple particle transport model used. The principal usefulness of the model in its present form is as a tool for the interpretation of the influence on fatigue life of surface damage acquired in service.

76-1934

A Theoretical Investigation of the Multileaf Journal Bearing

K.P. Oh and S.M. Rohde

Research Laboratories, General Motors Corp., Warren, MI., J. Appl. Mech., Trans. ASME, 43 (2), pp 237-242 (June 1976) 6 figs, 11 refs

Key Words: Journal bearings, Lubrication, Finite element technique

The finite-element method is used to solve the compressible Reynolds equation which governs the fluid flow between the journal surface and the leaves in a multileaf journal bearing. The solution obtained is then coupled with the load-deflection equations of the leaves to obtain such information as liftoff speed and minimum film thickness. In addition, the load-deflection equations yield the initial preload on the journal, the startup torque, the stiffness coefficients, and the equivalent damping coefficients. Such details as leaf curvature, friction between leaves, and between leaves and journal surface are considered in the load-deflection equations. Results are obtained for a wide range of operating parameters.

BLADES

76-1935

Vibration Modes of Mistuned Bladed Disks

D.J. Ewins

Imperial College of Science & Technology, London, SW7 2BX, England, J. Engr. Power, Trans. ASME, 98 (3), pp 349-355 (July 1976) 4 figs, 6 refs

ASME Paper No. 75-GT-114

Key Words: Vibration measurement, Blades, Disks, Turbomachinery

A comprehensive experimental and theoretical investigation is reported with the object of resolving the uncertainties surrounding the effects of blade mistuning. A special experimental facility has been designed and built with which it is possible to measure bladed disk vibration under conditions of rotation and excitation which simulate closely those experienced in a turbomachine. The bladed disk testpieces have been specially designed and manufactured so that they may be very precisely tuned (or mistuned), and the whole apparatus has been designed to afford the maximum degree of control over all the relevant conditions. This paper describes a set of measurements and corresponding calculations of the many complex vibration modes possessed by a bladed disk when the blades are slightly mistuned.

76-1936

Vibration Characteristics of Composite Fan Blades and Comparison with Measured Data

C.C. Chamis

NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71893, 12 pp (1976) (presented at 17th Struct., Structural Dyn. and Mater. Conf., King of Prussia, PA., 5-7 May 76; sponsored by Am. Inst. of Aeron. and Astronautics, Am. Soc. of Mech. Engr., and Soc. of Autom. Engr.)

N76-21589

Key Words: Blades, Fans, Vibration response, Computer programs

The vibration characteristics of a composite fan blade for high-tip-speed applications were determined theoretically and the results compared with measured data. The theoretical results were obtained using a computerized capability consisting of NASTRAN coupled with composite mechanics by way of pre- and postprocessors. The predicted vibration frequencies and mode shapes were in reasonable agreement with the measured data. Theoretical results showed that different laminate configurations from the same composite system had only small effects on the blade frequency. However, the use of adhesively bonded titanium/beryllium laminar composites may improve considerably the blade vibration characteristics.

76-1937

Transonic Flow Analysis in Axial-Flow Turbomachinery Cascades by a Time-Dependent Method of Characteristics

R.A. Delaney and P. Kavanagh

Dept. of Mechanical Engineering and Engineering Research Inst., Iowa State Univ., Ames, IA., J. Engr. Power, Trans. ASME, 98 (3), pp 356-363 (July 1976) 14 figs, 8 refs

ASME Paper No. 75-GT-8

Key Words: Turbomachinery, Blades, Aerodynamic characteristics, Method of characteristics

Solutions for transonic flow in cascades are determined by a second-order time-dependent method of characteristics using bicharacteristics. The analysis method is based on unsteady, two-dimensional, compressible, inviscid flow with steady-state solutions computed as the asymptotic limit in time of transient solutions. Two turbine cascade cases are presented. The first involves subsonic flow throughout the cascade; the second involves subsonic inlet and discharge flows with transonic flow over a portion of the cascade passage. In both cases, the computed results for blade surface pressure distribution are compared with experimental data. Generally good agreement is shown.

CYLINDERS

76-1938

Vortex Shedding From a Cylinder Vibrating in Line with an Incident Uniform Flow

O.M. Griffin and S.E. Ramberg

Naval Research Laboratory, Washington, D.C., 20375 J. Fluid Mech., 75 (2), pp 257-271 (May 27, 1976) 10 figs, 20 refs

Key Words: Cylinders, Vortex shedding

A study has been made of the wake of a cylinder vibrating in line with an incident steady flow. The Reynolds number for the experiments was 190, and the vortex shedding was at all times synchronized with the vibrations of the cylinder, which were in a range of frequencies near twice the Strouhal shedding frequency for the stationary cylinder.

76-1939

Vibrations of a Row of Circular Cylinders in a Liquid

S.S. Chen

Argonne National Lab., Argonne, IL., Rept. No. ANL-CT-75-34, 41 pp (Apr 1975)

N76-22498

Key Words: Cylinders, Fluid-induced excitation, Periodic response, Harmonic excitation, Heat exchangers

The effects of interaction with surrounding liquid on the dynamic behavior of a row of circular cylinders are studied analytically. First, the hydrodynamic forces associated with cylinder motions are obtained using the potential flow theory. Then, a method of solution is presented for free vibration of a row of cylinders. Finally, steady state responses to harmonic excitations are presented. The results of the study have important application in the modeling of cross flow-induced vibration of heat exchanger tubes.

76-1940

Base Pressure of Oscillating Circular Cylinders

P.K. Stansby

Civil Engrg. Dept., Univ. of Salford, Salford, England, ASCE J. Engr. Mech. Div., 102 (EM4), pp 591-600 (Aug 1976) 6 figs, 11 refs

Key Words: Cylinders, Vortex-induced vibration

Experiments have been made to investigate the base pressure coefficients of circular cylinders oscillating transversely in a stream for a wide range of cylinder amplitudes and frequencies. This is thought to give a good indication of the variation in drag coefficient. The locking-on of vortex shedding at the cylinder frequency, associated with vortex-induced vibrations, was carefully studied. Locking-on at a third of the cylinder frequency was found to produce especially low base pressures, i.e., high drags.

DUCTS

76-1941

Design of Optimum Acoustic Treatment for Rectangular Ducts with Flow

R.E. Motsinger, R.E. Kraft and J.W. Zwick

General Electric Co., Evendale, OH., ASME Paper No. 76-GT-113

Key Words: Ducts, Rectangular bodies, Optimization, Acoustic properties, Modal analysis

A design optimization technique for acoustic treatment in rectangular ducts with uniform mean flow is presented. The technique is based on the acoustic wave solution in terms of series of characteristic duct modes. The analysis allows multiple axial treatment sections along the length of the duct and requires a known modal characterization of the sound source. Conditions of acoustic pressure and acoustic velocity continuity are used to match modal solutions at planes of impedance discontinuity in the duct. Experimental techniques for obtaining this modal characterization are presented.

76-1942

Experimental-Analytical Correlation of Optimum Duct Acoustic Liner Performance

J.D. Patterson, D.T. Sawdy and R.J. Beckemeyer

The Boeing Co., Wichita, KS., ASME Paper No. 76-GT-126

Key Words: Ducts, Rectangular bodies, Acoustic linings

Mode matching and segmented duct analytical models have been developed to take advantage of relative placement of liner segments in the design of optimal duct acoustic liners of one, two, and three segments. This paper presents experimental results which were obtained for liners installed in a rectangular duct for the case with no mean airflow through the duct. Excellent correlation is shown between the analytical and experimental data, thus verifying the analytical procedures used to design the optimum segmented lining configurations.

76-1943

Analytical and Experimental Studies of an Optimum Multisegment Phased Liner Noise Suppression Concept

D.T. Sawdy, R.J. Beckemeyer and J.D. Patterson

Boeing Co., Wichita, KS., Rept. No. NASA-CR-134960; D3-9812-1, 128 pp (May 1976)

N76-22976

Key Words: Noise reduction, Acoustic linings, Ducts, Rectangular bodies, Mathematical models

Results are presented from detailed analytical studies made to define methods for obtaining improved multisegment lining performance by taking advantage of relative placement of each lining segment. Properly phased liner segments reflect and spatially redistribute the incident acoustic energy and thus provide additional attenuation. A mathematical model was developed for rectangular ducts with uniform mean flow. Segmented acoustic fields were represented by duct eigenfunction expansions, and mode-matching was used to ensure continuity of the total field. Parametric studies were performed to identify attenuation mechanisms and define preliminary liner configurations. An optimization procedure was used to determine optimum liner impedance values for a given total lining length, Mach number, and incident modal distribution.

76-1944

Acoustic Liner Optimum Impedance for Spinning Modes with Cut-Off Ratio as the Design Criterion

E.J. Rice

NASA Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-73411; E-8741, 11 pp (1976)

N76-23943

Key Words: Acoustic linings, Acoustic impedance, Design techniques

A new acoustic liner design procedure based upon model cut-off ratio is outlined. Proposed experiments to substantiate this design procedure are outlined.

76-1945

A Theoretical and Experimental Study of the Generation and Reduction of Multiple Higher-Order Modes in a Hard-Walled, Anechoically-Terminated Cylindrical Duct

M.J. Oslac

Ph.D. Thesis, The Pennsylvania State Univ., 1975, 197 pp

UM 76-18, 388

Key Words: Ducts, Cylindrical bodies, Noise reduction, Acoustic linings

While significant strides have been made in the reduction of noise from turbomachinery, fans/compressors, and from air-moving systems in general, there is still a need for ongoing fundamental research to optimize the performance of present technology and devise new methods of noise reduction. This thesis responds to these needs by presenting a method whereby acoustic duct liners can be investigated in terms of

their optimization and by developing the fundamentals for the active noise reduction technique of phased cancellation. The optimization of acoustic duct liners can be performed by utilization of the Spinning Mode Synthesizer (SMS) originally developed at The Pennsylvania State University's Noise Control Laboratory and expanded on, in terms of its application to in-duct testing, in this thesis. The SMS is a controllable device whereby single, multiple and/or combinations of higher order duct modes can be generated and propagated in cylindrical ducts. The results presented in this thesis show excellent agreement with theoretical predictions.

PIPES AND TUBES

76-1946

Dynamic Characteristics of an Underwater Pipeline

A.R. Desai

Ph.D. Thesis, Texas A&M Univ., 1975, 114 pp

UM 76-17, 352

Key Words: Pipelines, Underwater pipelines

The current upsurge in offshore drilling for oil and gas and new deep water terminals for the supertankers has created a demand for deep water pipelines. These pipelines are being laid in deeper and more hostile waters than ever before. This study represents a novel approach with wide band random excitation being applied to the pipe model through inertial coupling. This represents an improvement over the conventional harmonic excitation applied at reduced Reynolds numbers. The analytical model results in a simple solution for the mean square response. The solution is in excellent agreement with the experimental results. Finally, two areas of further research are identified. These include the linearized model for fluid damping and the measurement of actual prototype excitation spectra.

76-1947

An Experimental Investigation of the Wall Pressure Fluctuations in Piping Containing Simple Control Devices

A.V. Karvelis

Ph.D. Thesis, The Pennsylvania State Univ., 1975, 273 pp

UM 76-18, 384

Key Words: Pipes (tubes), Sound transmission

An experimental investigation of the wall pressure field characteristics associated with several control devices is reported. The investigation was conducted using a 3.01 inch inside diameter pipe containing several control/throttling devices using air as the working fluid and operating above critical pressure drop. Cross-correlations and narrow band spectrum levels were measured using several flush mounted wall pressure transducers located upstream and downstream of the devices. A theory is presented which relates the filtered cross covariance obtained from two wall pressure transducers to the true sound power generated by the device. This theory, which is based on the space-time correlation properties of one dimensional random acoustic fields, is verified by experiment.

PLATES AND SHELLS

76-1948

Natural Frequencies of Rectangular Flat Plates with Various Edge Conditions

Engineering Sciences Data Unit, London, England, Rept. No. ESDU-75030, 52 pp (Nov 1975) (supersedes ESDU-66019)

Availability: NTIS, Attn: ESDU, Springfield, VA N76-21584

Key Words: Rectangular plates, Natural frequencies

This report presents data in graphical form for calculating the natural frequencies of flat isotropic rectangular plates for modes up to at least (3.1) and (1.3). It covers all the 36 possible combinations of free, simply-supported and clamped edge conditions, and a method is provided to allow the estimation of natural frequencies of plates under the action of uniform biaxial in-plane loads. Each combination of edge conditions is dealt with on a single graph which presents a non-dimensional frequency coefficient which avoids either very large or very small values. The report covers any respect ratio and so allows the natural frequencies of beams to be estimated within certain stated limitations. The data are presented for the commonly used engineering materials which have a Poisson's ratio of 0.3 and guidance is provided on the effect of departure from this value in other materials. An appendix to the report provides approximate data for calculating buckling stresses under biaxial loading for plates with most of the possible combinations of edge conditions. These buckling loads are required to estimate the effect of in-plane loading on natural frequencies.

76-1949

The Flexural Vibrations of a Line-Stiffened Plate with Fluid Loading

V. Williams and F.J. Fahy

Inst. of Sound and Vibration Res., Southampton Univ., England, Rept. No. ISVR-TR-74, 87 pp (Feb 1975)

Sponsored by Admiralty Underwater Weapons Estab.

N76-22590

Key Words: Plates, Flexural vibrations, Fluid-induced excitation, Stiffened plates, Computer programs

Various approaches to the problem of wave propagation on a fluid loaded plate bearing stiffening beams are presented. The vibrations of an infinite fluid loaded plate bearing a finite number of parallel line stiffeners were calculated.

76-1950

Vibration and Sound Radiation of a Plate

R.J. Hannon

Ph.D. Thesis, The Pennsylvania State Univ., 1975, 117 pp

UM 76-17, 172

Key Words: Plates, Vibrating structures, Noise source identification

Because of their many vibratory resonances, plates are mechanically soft and their suspending structures have a considerable effect on their vibration and sound radiation. Experimental evaluation of acoustic properties of plates is therefore difficult. Plates of different shapes and dimensions were supported in such a way as to eliminate effects of the support on the vibration, and the velocity amplitudes due to point forces were recorded by phonograph cartridge and microphones in the near sound field.

76-1951

A Finite Element Method for the Free Vibration of Plates Allowing for Transverse Shear Deformation

T.A. Rock and E. Hinton

Dept. of Civil Engrg., Univ. of Wales, Singleton Park, Swansea SA28PP, Wales, Computers and Struc., 6 (1), pp 37-44 (Feb 1976) 4 figs, 25 refs

Key Words: Plates, Free vibration, Transverse shear deformation effects, Finite element technique

An isoparametric quadrilateral plate bending element is introduced and its use for the free vibration analysis of both thick and thin plates is examined. Plates of rectangular planform and of orthotropic materials are analyzed and excellent results are obtained. The element performance is assessed by comparison with well established analytical and numerical solutions based on Mindlin's thick plate theory, three dimensional elasticity solutions and solutions based on thin plate theory. The ease with which the element may be implemented is stressed. The use of an eigenvalue economizer which produces considerable economy in the computer solution is demonstrated. Various mass lumping schemes and numerical integration rules used in the construction of the element mass matrix are also examined.

76-1952

Mode Approximation Technique Applied to Finite Deflections of an Impulsively Loaded Viscoplastic Plate

C.T. Chon and P.S. Symonds

Dept. of Engrg., Brown Univ., Providence, RI., Rept. No. TR-1, 45 pp (Nov 1975)

AD-A024 862/5GA

Key Words: Plates, Viscoplastic properties, Sandwich structures, Modal analysis

The extension of the 'mode approximation' technique to finite deflections is illustrated in this paper by application to a fully clamped plate which is impulsively loaded and whose material exhibits rigid-perfectly plastic or viscoplastic behavior. Deflections up to about ten plate thicknesses are treated. The approximation technique requires finding 'instantaneous mode' form solutions at a sequence of times, satisfying the current equations of material behavior, edge constraint, and dynamics including finite deflections terms.

76-1953

Wave Propagation in the Linear Theory of Elastic Shells

H. Cohen

Dept. of Civil Engrg., Univ. of Manitoba, Winnipeg, Manitoba, Canada, J. Appl. Mech., Trans. ASME, 43 (2), pp 281-285 (June 1976) 8 refs

Sponsored by the National Res. Council of Canada

Key Words: Shells, Plates, Shock wave propagation, Elastic properties, Linear theories

The problem of wave propagation in elastic shells within the framework of a linear theory of a Cosserat surface is treated using the method of singular wave curves. The equations for determining the speeds of propagation and their associated wave mode shapes are obtained in a form involving the speeds of propagation in Cosserat plates and the curvature of the shell. A number of special cases in which the speeds and mode shapes simplify are considered. In particular, these special cases are shown to include as examples, certain systems of waves in elastic shells whose middle surfaces are the surface of revolution, the circular cylinder, the sphere, and the right helicoid.

76-1954

Nonlinear Vibration and Flutter of Stressed Skew Panels

P.S. Nair and S. Durvasula
Dept. of Aeron. Engrg., Indian Inst. of Science, Bangalore, India, Rept. No. AE-331S-Rev; AE-313S, 47 pp (Oct 1975) (Supersedes AE-313S)
N76-22585

Key Words: Panels, Skew plates, Flutter

Von Karman plate equations are used to study the influence of nonlinearity on the period of vibration in unstressed and stressed skew plates. The equations of motion for flutter derived through Lagrange's equations are solved by an analog computer and also by direct numerical integration. The nature of flutter motion of buckled and unbuckled panels and the transitions from the buckled stable to flat stable configurations with increasing dynamic pressure are discussed. The influence of the aerodynamic damping term on the dynamic pressure parameter is also examined.

76-1955

On the Large-Deformation Theory of Fluid-Filled Shells of Revolution

A.E. Engin

Dept. of Engrg. Mech., The Ohio State Univ., Columbus, OH., Shock and Vibration Digest, 8 (8), pp 35-47 (Aug 1976) 3 figs, 20 refs

Key Words: Shells of revolution, Fluid filled containers

This paper is concerned with the dynamic analyses of fluid-filled shells of revolution. The shells can experience large displacements and rotations. They are membrane shells and can be subjected to general axisymmetric loads of considerable magnitude. Linear shell theory can be used only within a limited range of loading, but numerical values are in good agreement with experimental results for most engineering applications. The purpose of this paper is to develop a formulation of the theory that is applicable to biological systems composed of fluid-filled membranes, in which can occur large displacements, rotations and large elastic strains.

76-1956

Vibrations and Buckling of Axially Loaded Stiffened Cylindrical Shells with Elastic Restraints

A. Rosen and J. Singer

Dept. of Aeronautical Engrg. Technion-Israel Inst. of Technology, Haifa, Israel, Intl. J. Solids Struc., 12 (8), pp 577-588 (1976) 5 figs, 37 refs

Sponsored by the Air Force Office of Scientific Res.

Key Words: Cylindrical shells, Edge effect

A theory is derived for calculation of the influence of elastic edge restraints on the vibrations and buckling of stiffened cylindrical shells. The stiffeners are considered "smeared" and the edge restraints can be axial, radial, circumferential or rotational. Extensive computations are performed for special kinds of stringer-stiffened shells, and the theoretical predictions are compared with experimental results. A method of definition of equivalent elastically restrained boundary conditions by use of vibration tests is discussed. Application of this technique to tests on 10 shells significantly reduces the scatter in the ratio of experimental to predicted buckling loads.

RINGS

76-1957

Vibration of Heterogeneous Mechanical Systems

B. Dizioglu

Progress Repts. of VDI (Fortschritt-Berichte der VDI Zeitungen) Series 11, No. 24, 80 pp (1976) 9 figs (Summarized in VDI-Z 118 (12) June 1976)
Availability: VDI Verlag GmbH, 4 Düsseldorf 1, Postfach 1139, Germany

Key Words: Forced vibration, Free vibration, Mechanical systems, Bars

In the report free and forced vibrations of a mechanical system are examined in detail. The system consists of a bar with one end fixed and a string attached to its free end and maintained under tension in the direction of equilibrium position of the bar at its second fixed point. Special cases of the system with variable mass and density are discussed in particular detail.

STRUCTURAL

76-1958

A Survey of the Optimal Design of Vibrating Structural Elements. Part I: Theory

N. Olhoff

Dept. of Solid Mech., The Technical University of Denmark, Lyngby, Denmark, Shock and Vibration Digest, 8 (8), pp 3-10 (Aug 1976) 61 refs

Key Words: Optimum design, Structural elements, Free vibration, Variational methods

This paper surveys the optimal design of elastic structural elements undergoing free vibrations. The unified variational technique is used to minimize the material volume of a one- or two-dimensional continuous element with a specific natural frequency.

SYSTEMS

NOISE REDUCTION

(Also see Nos. 1886, 1912, 1943, 1976, 1980, 1981, 1983, 1984, 2005, 2007, 2012)

76-1959

Noise Abatement and Internal Vibrational Absorption in Potential Structural Materials

L. Kaufman, S.A. Kulin and P.P. Neshe

Manlabs, Inc., Cambridge, MA., Rept. No. AMMRC-CTR-76-3, 52 pp (Jan 1976)

AD-A022 784/3GA

Key Words: Acoustic absorption, Noise reduction, Vibration isolators

Efforts have been directed toward achieving higher yield strengths in high damping cobalt-iron base alloys by adding nickel, aluminum and manganese. Substantial increases have been achieved through aluminum and manganese additions at low levels. The range of loss factors and yield strengths which are attainable exceed currently available commercial materials. The effects of alloying additions of iron and manganese as well as reduction in grain size are being investigated as a means for reducing the brittleness of copper-aluminum-nickel alloys which exhibit thermoelastic martensitic transformations. These transformations provide high damping characteristics and high loss factors.

76-1960

Sound Attenuator for DO 27

K. Seifert

Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Zentralabteilung Luftfahrttechnik, Oberpfaffenhofen, West Germany, Rept. No. DLR-IB-555-74/4, 21 pp (July 1974)

(In German)

N76-22203

Key Words: Aircraft noise, Noise reduction, Acoustic absorption

Two sound attenuators for the engine of the relatively noisy DO 27 H and DO 27 A aircraft were constructed and tested in an anechoic chamber. The choice of a combined attenuator, consisting of a resonator and absorption part, containing a pipe lining and a muffler, is discussed. The flight noise of the DO 27 H is dealt with and the dimensions of the sound attenuator are detailed. Measuring equipment and measuring results are discussed; it is concluded that the level of attenuation reached will probably be sufficient.

76-1961

Coupling of Helmholtz Resonators to Improve Acoustic Liners for Turbofan Engines at Low Frequency

L.W. Dean

Pratt and Whitney Aircraft, East Hartford, CT., Rept. No. NASA-CR-134912; PWA-5311, 66 pp (Aug 1975)

N76-21210

Key Words: Acoustic linings, Fans, Turbine components, Noise reduction

An analytical and test program was conducted to evaluate means for increasing the effectiveness of low frequency sound absorbing liners for aircraft turbine engines. Three schemes for coupling low frequency absorber elements were considered. These schemes were analytically modeled and their impedance was predicted over a frequency range of 50 to 1,000 Hz. The increased effectiveness of the coupled resonator concept for attenuation of low frequency broad spectrum noise is demonstrated.

76-1962

Checklists for Along-the-Path Noise Control

V. Salmon

Industrial Noise Services, Inc., 543 Bryant St., Palo Alto, CA., Noise Control Engr., 6 (2), pp 66-73 (Mar-Apr 1976) 10 refs

Key Words: Noise reduction, Industrial facilities

A series of ordered checklists concerned with control of noise along paths in gases, liquids, and solids is presented. In the lists, specific and representative problem areas, along with the appropriate noise-control techniques, materials, and devices are noted. Although the approach is chiefly in terms of industrial noise, the discussion will apply to a wide variety of problems in many fields. The lists also serve two other purposes: as a framework to which noise control engineers can add items from their own experience; and as a means of revealing gaps in the armamentarium of the engineer, where new approaches, materials, and devices are needed. The references provide a general background with the emphasis on practical applications.

76-1963

Grain Elevator Noise Control: Two Case Studies

Shiner and Associates, Skokie, IL., and Kamperman Associates, Inc., Downers Grove, IL., Illinois Inst. for Environmental Quality, Rept. No. IIEQ-76-02, 50 pp (Jan 1976)

PB-251 655/7GA

Key Words: Industrial facilities, Noise reduction

There are approximately 1,500 grain elevators in Illinois. The level of activity associated with grain elevators during the harvest season is extremely high. This seasonal noise can have a significant impact on the small towns which surround many grain elevators. These two studies identify and measure the acoustic emissions and recommend corrective actions to control the noise associated with grain elevator operations.

76-1964

Community Reaction to Noise From a Construction Site

J.B. Large and J.E. Ludlow

Inst. of Sound and Vibration Res., The Univ. of Southampton, Southampton S09 5NH, England, Noise Control Engr., 6 (2), pp 59-65 (Mar-Apr 1976) 6 figs, 6 refs

Key Words: Noise generation, Construction industry, Human response

Reactions to noise from construction road traffic, and other sources are compared in terms of annoyance and other attitudinal factors due to exposure. The actual execution of the survey is described fully elsewhere but is described briefly here since it represents a novel and particularly economic means of gathering data on noise impact. The survey reported here was carried out around a single road construction site. The situation investigated was, by definition, a special case, since every intrusion into a residential area will be unique. Nevertheless, it is suggested that the results obtained offer some insight into the effect of construction noise on a residential community.

AIRCRAFT

(Also see Nos. 1889, 1914, 1917, 1960, 1961)

76-1965

Dynamics and Identification of Flexible Aircraft

W.R. Wells

Dept. of Aerospace Engrg., Cincinnati Univ., Cincinnati, OH., Rept. No. NASA-CR-2672, 68 pp (Apr 1976)

N76-21158

Key Words: Aircraft, Parameter identification

The equations of motion and a maximum likelihood parameter identification formulation are developed for a flexible aircraft. The various levels of approximation associated with the modal substitution representation of the elastic displacement field are discussed and illustrated when appropriate. The necessary extension of the parameter set of stability and control derivatives due to the aeroelastic effects is obtained.

76-1966

Application of Optimal Input Synthesis to Aircraft Parameter Identification

N.K. Gupta, R.K. Mehra and W.E. Hall, Jr.

Systems Control, Inc., Palo Alto, CA., J. Dyn. Syst., Meas. and Control. Trans. ASME, 98 (2), pp 139-145 (June 1976) 6 figs, 13 refs

Sponsored by NASA and Office of Naval Research

Key Words: Aircraft, Parameter identification, Structural synthesis, Frequency domain

This paper considers an application of the Frequency Domain Input Synthesis procedure for identifying the stability and control derivatives of an aircraft. In previous studies, the input design has mostly been carried out in the time-domain. However, by using a frequency-domain approach, criteria that are not easily handled by the time-domain approaches are utilized. Numerical results are presented for optimal elevator deflections to estimate the longitudinal stability and control derivatives subject to root-mean square constraints on the input. The applicability of the steady state optimal inputs to finite duration flight testing is reported.

76-1967

Aerodynamic Symmetry of Aircraft and Guided Missiles

P.H. Zipfel

Air Force Armament Lab., Eglin Air Force Base, FL., J. Aircraft, 13 (7), pp 470-475 (July 1976) 2 figs, 5 refs

Key Words: Aircraft, Missiles, Mathematical modeling

A technique is developed that takes advantage of the inherent configurational symmetries of aircraft and guided missiles to eliminate some force and moment derivatives. Starting with the Principle of Material Indifference, tensor analysis is employed to derive two simple conditions for vanishing aerodynamic derivatives. The results apply to derivatives of arbitrary order, taken with respect to linear and angular velocities, linear accelerations, and control surface deflections. Two charts are presented that sift out the vanishing derivatives up to second order for missiles with tetragonal symmetry, and up to third order for aircraft with reflectional symmetry.

76-1968

Dynamic Analysis of Aircraft Impact Using the Linear Elastic Finite Element Codes FINEL, SAP, and STARDYNE

P. Lundsager and S. Krenk

Danish Atomic Energy Commission, Riscoe, Rept. No. RISO-M-1817, 18 pp (Aug 28, 1975)

N76-21596

Key Words: Aircraft, Impact response, Computer programs

The static and dynamic response of a cylindrical/spherical containment to a Boeing 720 impact was computed using 3 different linear elastic computer codes. Stress and displacement fields are shown together with time histories for a point in the impact zone.

76-1969

Repetitive Flutter Calculations in Structural Design

R.T. Haftka and E.C. Yates, Jr.

Ill. Inst. of Technology, Chicago, IL., J. Aircraft, 13 (7), pp 454-461 (July 1976) 8 figs, 18 refs

Sponsored by NASA

Key Words: Aircraft vibration, Flutter

Some aspects of efficient model flutter analysis are investigated for use in aircraft structural design which may involve many iterations. Expressions for the generalized aerodynamic forces are derived which are separated into mode-dependent and mode-independent parts; this permits rapid recalculation of the forces when the modes are changed. The computer times required for the various parts of a single flutter analysis are presented for some example problems. These examples are used to compare the efficiency of using periodically updated natural vibration modes fixed modes with resizing methods that do not require the derivatives of any of the flutter parameters with respect to structural variables. The main computational penalty in updating modes is found to be in the recalculation of the modes, rather than in the calculation of the generalized aerodynamic forces. Flutter calculations also are examined for resizing methods that do require the derivatives of the flutter frequency, flutter speed, or flutter altitude with respect to design variables. The convergence of such derivatives with increasing number of modes is investigated with the aid of two examples. The poor convergence of the derivatives precluded comparison of the use of continually updated vs fixed modes for resizing methods that require such derivatives.

76-1970

Flutter of Asymmetrically Swept Wings

T.A. Weisshaar and J.B. Crittenden

Dept. of Aerospace and Ocean Engrg., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA., Rept. No. NASA-CR-146815, 32 pp (Mar 12, 1976) (Backup document for AIAA Synoptic scheduled for publication in AIAA Journal in Aug. 1976)

N76-21164

Key Words: Aircraft wings, Flutter

Two formulations of the oblique wing flutter problem are presented; one formulation allows only simple wing bending deformations and rigid body roll as degrees of freedom, while the second formulation includes a more complex bending-torsional deformation together with the roll freedom. Flutter is found to occur in two basic modes. The first mode is associated with wing bending-aircraft roll coupling and occurs at low values of reduced frequency. The second instability mode closely resembles a classical bending-torsion wing flutter event. This latter mode occurs at much higher reduced frequencies than the first. The occurrence of the bending-roll coupling mode is shown to lead to lower flutter speeds while the bending-torsion mode is associated with higher flutter speeds. The ratio of the wing mass moment of inertia in roll to the fuselage roll moment of inertia is found to be a major factor in the determination of which of the two instabilities is critical.

76-1971

Technical Evaluation Report of AGARD Specialists Meeting on Wing-with-Stores Flutter

W.J. Mykytow

AGARD, Paris, France, Rept. No. AGARD-AR-96; ISBN-92-835-1209-X, 13 pp (Feb 1976) (Meeting held at Münich, 9 Oct 1974 during 39th Meeting of Struct. and Mater. Panel)

N76-21163

Key Words: Aircraft wings, Wing stores, Flutter

The carriage of stores on wings significantly changes their dynamic characteristics and often adversely affects their flutter properties as a result of reduced wing frequencies and the introduction of critical frequency ratios together with inertia, elastic and aerodynamic coupling between loads. Adverse flutter characteristics and significantly lowered flutter speeds occur and these restrictions severely constrain the speed -- altitude performance envelope that can be achieved by an aircraft. The variety of stores that can be carried on modern tactical airplanes generates a need to accurately evaluate the literally thousands of possible store combinations which can be carried by such aircraft. Results are presented from a conference on information and procedures in use in the various NATO nations to solve the flutter problems associated with the carriage of external stores on wings. Nine presentations were given and are summarized. Recommendations concerning possible future efforts on the subject are given.

76-1972

Comparison of Supercritical and Conventional Wing Flutter Characteristics

M.G. Farmer, P.W. Hanson and E.C. Wynne

NASA, Langley Res. Ctr., Langley Station, VA., Rept. No. NASA-TM-X-72837, 9 pp (May 1976)

N76-22159

Key Words: Aircraft wings, Flutter, Wind tunnel test

A wind-tunnel study was undertaken to directly compare the measured flutter boundaries of two dynamically similar aeroelastic models which had the same planform, maximum thickness-to-chord ratio, and as nearly identical stiffness and mass distributions as possible, with one wing having a supercritical airfoil and the other a conventional airfoil. The considerations and problems associated with flutter testing supercritical wing models at or near design lift coefficients are discussed, and the measured transonic boundaries of the two wings are compared with boundaries calculated with a subsonic lifting surface theory.

76-1973

Comments on Measuring Techniques for Unsteady Derivatives

J.W.G. VanNunen

Fluid Dynamics Div., National Aerospace Lab., Amsterdam, Netherlands, Rept. No. NLR-MP-75020-U, 8 pp (May 1975)

N76-22171

Key Words: Aircraft, Free vibration, Forced vibration

Some experimental methods applied at present to the measurements of unsteady derivatives are reviewed. They include the forced oscillation and free oscillation methods partly focused on the analysis of overall loads and moments acting on oscillating aircraft models. Further attention is paid to the measurement of unsteady pressure distribution as an alternative procedure to get information about derivatives; this technique is hardly to be considered as a substitute to the previous method, but may be suitable in the development and validation of analytical prediction methods.

76-1974

Responses of Small Rigid Aircraft to Discrete and Continuous Gust Analysis. Phase 1. Final Report. Nov 1972 - Nov 1974

J. Petrakis and N. Miller

National Aviation Facilities Experimental Ctr., Atlantic City, NJ., Rept. No. AD-A020103/8; FAA-RD-74-160; FAA-NA-74-44, 121 pp (Dec 1975)

N76-21191

Key Words: Aircraft, Wind-induced excitation, Computer programs

An evaluation is made of methods developed for estimating longitudinal and lateral rigid-body responses of airplanes to random atmospheric turbulence. A computer program, evolved from this study, calculates general aviation aircraft stability derivatives from known geometric properties used as inputs for the calculation of aircraft response (also a developed part of the computer program). It was found that the two degrees-of-freedom rigid-body power spectral density analysis produced lower normal load factor responses than a similar single degree-of-freedom analysis for aircraft of gross weight from 3,000 to 17,500 pounds. Also to produce an equivalent discrete load factor for the two degrees-of-freedom analysis, a higher spectral velocity value must be used compared to that of the single degree-of-freedom approach.

76-1975

Introduction to a Fighter Aircraft Loading Standard for Fatigue Evaluation (Falstaff)

G.M. VanDijk and J.B. DeJonge

Structures and Materials Div., National Aerospace Lab., Amsterdam, Netherlands, Rept. No. NLR-MP-75017-U, 40 pp (May 1975)

N76-22598

Key Words: Aircraft, Fatigue life, Standards

Falstaff (Fighter Aircraft Loading Standard for Fatigue Evaluation), a loading history standard pertaining to fighter aircraft wing bending primarily governed by maneuver loadings, is derived in order to evaluate the fatigue performance of structural materials and components and to establish fatigue design charts. The present report concerns a joint international development effort involving Dutch, German, and Swiss institutes. Details are presented with regard to the general development philosophy and data sources considered. The development procedures followed are summarized. The results of some preliminary validation tests are reported.

76-1976

Experimental Evaluation of NAS Miramar Hush House (Project P-114) Volume 1

W.P. Sule and E.T. Pulcher

Ground Support Equipment Dept., Naval Air Engineering Center, Lakehurst, NJ., Rept. No. NAEC-GSED-96-Vol-1, 147 pp (Feb 1976) (See also Vol 2, AD-A024 404)

AD-A024 403/8GA

Key Words: Aircraft noise, Noise reduction, Model testing, Test facilities

This report summarizes the results of an extensive experimental test and evaluation of the new NAS Miramar Hush House. The tests consisted of both aero-thermodynamic and acoustic data acquisition. Four different aircraft (A-4, F-8, F-4, F-14) were run in the facility and acoustic data was obtained on two of the aircraft (F-4, F-14). The results of the full size testing were compared with 1/15th scale model tests results to estimate the reliability of scale model tests for this application.

76-1977

Sources and Characteristics of Interior Noise in General Aviation Aircraft

J.J. Catherines and S.K. Jha

Cranfield Inst. of Technology, England, Rept. No. NASA-TM-X-72839, 24 pp (Apr 1976) (presented at 91st Meeting Acoust. Soc. Am., Washington, D.C., 5-9 Apr 1976)

N76-21990

Key Words: Aircraft noise, Noise source identification, Sound transmission, Acoustic tests

A field study was conducted to examine the interior noise characteristics of a general aviation aircraft. The goals were to identify the major noise sources and their relative contribution and to establish the noise transmission paths and their relative importance. Tests were performed on an aircraft operating under stationary conditions on the ground. Results show that the interior noise level of light aircraft is dominated by broadband, low frequencies (below 1,000 Hz). Both the propeller and the engine are dominant sources, however, the contribution from the propeller is significantly more than the engine at its fundamental blade passage frequency. The data suggest that the airborne path is more dominant than the structure-borne path in the transmission of broadband, low frequency noise which apparently results from the exhaust.

76-1978

Noise Level Measurements in Cockpits and Cabins of DFVLR, Oberpfaffenhofen Flight Unit Aircraft (Results of a First Series of Measurements)

H. Galleithner

Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Zentralabteilung Luftfahrttechnik, Oberpfaffenhofen, West Germany, Rept. No. DLR-IB-555-74/11, 20 pp (Dec 1974)

(In German)

N76-22204

Key Words: Aircraft noise, Noise measurement

The noise, at car level, of Dornier DO 27 and 28, Beech 65, Piaggio Pi 149 D and Cessna 207 aircraft was measured during typical flight phases on the runway, during takeoff, and during cruising. Results were tabulated. It is shown that the noise level of the different aircrafts can be classified, transforming the dB (A)-level into a dimensionless characteristic performance number, which is a measure for the effective engine performance as a percentage of the continuous performance.

76-1979

Establishing Noise Criteria for Residential Living in Areas Surrounding Commercial Aviation Airports

MAN-Acoustics and Noise, Inc., Seattle, WA., Rept. No. AD-A021683/8; MAN-1011/FAA-RD-75-211, 68 pp (Nov 1975)

N76-23946

Key Words: Aircraft noise, Airports, Human response

Four different airport noise conditions were simulated. Three conditions involved day flights of 150 aircraft with average Noise Exposure Forecast (NEF) values of 36.9, 32.5, and 26.9. The fourth condition added 18 night flights which resulted in a mean NEF of 32.9. Interference with daily living activities and annoyance responses to the four conditions were obtained.

76-1980

Noise Reduction as Affected by the Extent and Distribution of Acoustic Treatment in a Turbofan Engine Inlet

G.L. Minner and L. Homyak

NASA, Lewis Res. Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71904; E-8693, 18 pp (1976)

N76-23268

Key Words: Engine noise, Noise reduction

An inlet noise suppressor for a TF-34 engine designed to have three acoustically treated rings was tested with several different ring arrangements. The configurations included: all three rings; two outer rings; single outer ring; single intermediate ring, and finally no rings. It was expected that as rings were removed, the acoustic performance would be degraded considerably. While a degradation occurred, it was not as large as predictions indicated. The prediction showed good agreement with the data only for the full-ring inlet configuration.

76-1981

Effects of Perforated Flap Surfaces and Screens on Acoustics of a Large Externally Blown Flap Model

R.J. Burns, D.J. McKinzie, Jr. and J.M. Wagner
NASA, Lewis Res. Ctr., Cleveland, OH., Rept. No. NASA-TM-X3335; E8559, 41 pp (Apr 1976)
N76-22156

Key Words: Aircraft noise, Noise reduction

Various model geometries and combinations of perforated flap surfaces and screens mounted close to the flap surfaces were studied for application to jet-flap noise attenuation for externally blown flap, under-the-wing aircraft. The efforts to reduce jet-flap interaction noise were marginally successful. Maximum attenuations of less than 4 db in overall sound pressure level were obtained in the flyover plane. Noise reductions obtained in the low-to-middle-frequency ranges (up to 7 db) were generally offset by large increases in high-frequency noise (up to 20 db).

76-1982

Status Report - Subsonic Aircraft Noise Reduction

J.W. Little and R.E. Russell
Boeing Commercial Airplane Co., Seattle, WA., ASME Paper No. 76-GT-116

Key Words: Aircraft noise, Noise reduction

The design process for a subsonic commercial transport aircraft is discussed with emphasis on noise considerations. A review of the process for identifying component noise levels is followed by a description of the design for noise reduction of typical components. A discussion of system constraints in the practical application of noise-reduction concepts is followed by comments on the need to include a reasonable design tolerance. Some aspects of the tradeoff between noise reduction and performance are described. Finally, a projection is made of future projected noise reductions based on yet-to-be-accomplished research programs.

76-1983

Noise Reduction Tests of Large-Scale-Model Externally Blown Flap Using Trailing-Edge Blowing and Partial Flap Slot Covering

D.J. McKinzie, Jr., R.J. Burns and J.M. Wagner
NASA, Lewis Res. Ctr., Cleveland, OH., Rept. No. NASA-TM-X-3379, E-8598, 65 pp (Apr 1976)
N76-22977

Key Words: Aircraft noise, Noise reduction

Noise data were obtained with a large-scale cold-flow model of a two-flap, under-the-wing, externally blown flap proposed for use on future STOL aircraft. The noise suppression effectiveness of locating a slot conical nozzle at the trailing edge of the second flap and of applying partial covers to the slots between the wing and flaps was evaluated. Overall-sound-pressure-level reductions of 5 db occurred below the wing in the flyover plane. Existing models of several noise sources were applied to the test results. The resulting analytical relation compares favorably with the test data. The noise source mechanisms were analyzed and are discussed.

76-1984

Phase 2 Program on Ground Test of Refanned JT8D Turbofan Engines and Nacelles for the 727 Airplane. Volume 3: Ground Tests. Final Report

Boeing Commercial Airplane Co., Seattle, WA., Rept. No. NASA-CR-134799; D6-42440-3-Vol-3, 350 pp (Dec 1975)
N76-21189

Key Words: Aircraft engines, Acoustic tests, Noise reduction

The NASA Refan Program included full-scale performance and noise ground tests of both a current production (JT8D-15) and a refanned (JT8D-115) engine. A description of the two ground tests including detailed propulsion, noise, and structural test results is presented. The primary objectives of the total test program were comparison of JT8D-15 and JT8D-115 overall propulsion system performance and noise characteristics and determination of incremental component noise levels. Other objectives of the test program included: (1) determination of acoustic treatment effectiveness; (2) measurement of internal sound pressure levels; (3) measurement of inlet and exhaust hardware performance; (4) determination of center-engine surge margin; and (5) evaluation of certain structural characteristics associated with the 727 refan center-engine inlet duct and JT8D refan engine exhaust system. The JT8D-15 and -115 tests were conducted during September 1974 and January to March 1975, respectively.

76-1985

Small Scale Noise and Wind Tunnel Tests of Upper Surface Blowing Nozzle Flap Concepts. Volume 1. Aerodynamic Test Results

D.J. Renselaer, R.S. Nishida and C.A. Wilkin
Aircraft Div., Rockwell International Corp., Los Angeles, CA., Rept. No. NASA-CR-137747, 143 pp (Dec 1975)
N76-21159

Key Words: Aircraft, Propulsion systems, Wind tunnel tests, Acoustic tests

The results and analyses of aerodynamic and acoustic studies conducted on the small scale noise and wind tunnel tests of upper surface blowing nozzle flap concepts are presented. Various types of nozzle flap concepts were tested. These are an upper surface blowing concept with a multiple slot arrangement with seven slots (seven slotted nozzle), an upper surface blowing type with a large nozzle exit at approximately mid-chord location in conjunction with a powered trailing edge flap with multiple slots (split flow or partially slotted nozzle). In addition, aerodynamic tests were continued on a similar multi-slotted nozzle flap, but with 14 slots. All three types of nozzle flap concepts tested appear to be about equal in overall aerodynamic performance but with the split flow nozzle somewhat better than the other two nozzle flaps in the landing approach mode.

76-1986

Small Scale Noise and Wind Tunnel Tests of Upper Surface Blowing Nozzle Flap Concepts. Volume 2. Acoustic Test Results

Y. Kadman

Rockwell International Corp., Los Angeles, CA., Rept. No. NASA-CR-137748; BBN-3130, 100 pp (Jan 1976) (prepared by Bolt Beranek and Newman, Inc., Cambridge, MA)
N76-21160

Key Words: Aircraft, Propulsion systems, Wind tunnel tests, Acoustic tests

Results are summarized of acoustic tests on two advanced concepts of upper-surface-blowing propulsive lift devices.

BIOENGINEERING

(See No. 1955)

BRIDGES

(Also see No. 1930)

76-1987

The Performance of Lapped Splices Under Rapid Loading

T. Rezansoff, M.P. Bufkin, J.O. Jirsa and J.E. Breen
Center for Highway Research, Texas Univ. at Austin, Austin, TX., Rept. No. CFHR-3-5-72-154-2, FHWA/RD-76-S0457, 108 pp (Jan 1975) (prepared in cooperation with Texas Highway Dept., Austin, TX)
PB-251 973/4GA

Key Words: Dynamic response, Bridges (structures), Reinforced concrete, Finite difference theory

The impact or dynamic response and resistance of structures or structural components has been of increasing interest in recent years. The failures of lapped splices at the bases of some concrete highway support structures during the San Fernando earthquake led to questions as to the suitability and adequacy of a lapped splice subjected to fast loading rates. In addition, the damage produced by hurricanes and tornadoes surpasses earthquake damage and gives added impetus to the study of structural behavior under dynamic loads. In this investigation the behavior of lapped splices subjected to impact loading was studied. The objective was to compare the strength and behavior of splices under static and dynamic loads and to determine whether the design provisions based primarily on static tests could be relied on under dynamic loading conditions.

76-1988

Binary Flutter of Suspension Bridge Deck

Y. Nakamura and T. Yoshimura

Res. Inst. for Applied Mech., Kyushu University, Fukuoka, Japan, ASCE J. Engr. Mech. Div., 102 (EM4), pp 685-700 (Aug 1976) 7 figs, 12 refs

Key Words: Suspension bridges, Flutter, Wind tunnel tests

Wind tunnel experiments on models of suspension bridge deck sections with plate girders of various heights are made to show that binary flutter of suspension bridge deck sections can be classified into three types which have different mechanisms of excitation; i.e., the classical type flutter, the single-degree-of-freedom type, and the intermediate type. Analyses on an energy equation of fluff structures with many degrees-of-freedom are also given to establish the theoretical basis of the classification of binary flutter. Although the geometry of the deck section is found to be the most dominant parameter that influences the type of flutter, it may also depend on various other parameters. The uncoupled frequency ratio is chosen, among others, and its effects on the three types of binary flutter are investigated.

BUILDING

76-1989

Investigation of Wind Damage in the Metropolitan Washington, D.C. Area, April 3-4, 1975

F.Y. Yokel, C.W. Yancey, L.E. Cattaneo and R.D. Marshall

National Bureau of Standards, Washington, D.C., Rept. No. NBS-TN-909, 68 pp (May 1976)
Sponsored in part by Defense Civil Preparedness Agency, Washington, D.C.
PB-252 681/2GA

Key Words. Buildings, Wind-induced excitation

A limited investigation was conducted of wind damage that occurred on April 3 and 4, 1975 in the Metropolitan Washington, D.C. area. Meteorological data indicate that the winds were somewhat less severe than those that should be anticipated by designers. Thus, most of the observed damage reflects inadequacies in design or construction. Damage was observed in occupied buildings, as well as in buildings under construction. Damaged elements of occupied buildings included. Masonry curtain walls; masonry gable walls; masonry veneer; roofs with overhangs; roofing; and cladding. Damaged elements of buildings under construction included roofs and masonry walls.

76-1990

Analysis and Design of Tube-Type Tall Building Structures

H. deClercq and G.H. Powell

Earthquake Engrg. Res. Ctr., California University, Berkeley, CA., Rept. No. EERC-76-5, 210 pp (Feb 1976)

PB-252 220/9GA

Key Words: Multistory buildings, Automated design, Macroelement method, Joints (junctions)

Tube-type structures for tall buildings generally consist of large numbers of members connected at an equally large number of joints. This causes the 'exact' analysis of such structures to be expensive, and manual sizing of members during design to be tedious. In this report a method, called the 'Macroelement Method,' is presented for the approximate analysis of three-dimensional tube-type frames consisting of horizontal beams and vertical columns connected at rigid joints. A linear elastic three dimensional analysis can be performed very economically by this method for buildings of arbitrary plan, including such structures as bundled tube frames. The macroelement method is a variation of the finite element method, in which a single element embraces a rectangular portion of frame consisting of several columns and several beams. Elements are connected at a small number of nodes. Shape functions are assumed over the region of each element to express the displacements of the beam-column joints in terms of the displacements of the nodes.

76-1991

Influence of Canyon on Soil-Structure Interaction

H.L. Wong, M.D. Trifunac and K.K. Lo

California Inst. of Tech., Pasadena, CA., ASCE J. Engr. Mech. Div., 102 (EM4), pp 671-684 (Aug 1976) 5 figs, 14 refs

Key Words: Interaction: soil-structure, Seismic design, Buildings, Secondary waves

The exact solution of the dynamic response of a shear wall on an elastic half space with a canyon having semicircular cross section is presented for excitation by plane SH-waves. It is shown that the driving forces and compliances in the soil-structure interaction problem depend directly on the existence of a canyon. For different angles of incident SH-waves the existence of a canyon may shield or amplify the building motions for the waves whose wavelengths are short compared to the canyon dimensions. In most cases building motions are smaller when the building is located behind the canyon with respect to incident waves. However, these motions may be amplified when the building is placed in front of the canyon. The results of this analysis suggest that the shielding of building foundations by canyons or trenches may not be very useful from the practical engineering point of view.

76-1992

Structural Damage Caused by the 1976 Guatemala Earthquake

M.A. Sozen and J. Roesset

Dept. of Civ. Engrg., Illinois Univ. at Urbana-Champaign, IL., Rept. No. UILV-ENG-76-2003, 87 pp (Mar 1976)

PB-252 350/4GA

Key Words: Earthquake damage

This report contains a preliminary description of the response of engineered construction in Guatemala City to the earthquakes of 4 and 6 February 1976. The technical information contained in the report is limited primarily to photographic evidence. No quantitative analysis is included. It is believed that an early release of the available information will be of value to emphasize some of the structural phenomena which do not need analysis and to put into perspective the level of damage experienced in the city.

CONSTRUCTION

(See No. 1964)

HELICOPTERS

(Also see No. 2018)

76-1993

Energy-Absorbing Materials for Improving Helicopter Crashworthiness

C.E. Kimball and R.C. DeHart
Southwest Research Inst., San Antonio, TX., 27 pp (Mar 1976)
AD-A023 006/0GA

Key Words: Helicopters, Energy absorption, Honeycomb, Foams, Collision research (aircraft)

The purpose of the program was to identify materials which were not only suitable for structural components but were capable of absorbing energy at acceptable deceleration levels in a crash environment. After review of available materials for their energy absorption capability, five candidate materials were selected and a test program initiated to demonstrate their attenuation properties. Those selected were three types of honeycomb, a rigid foam, and a flexible foam.

HUMAN

(Also see No. 1964)

76-1994
Dynamic Response of Intervertebral Joints of a Seated Farm Machine Operator in the Range 5-50 Hz
O.A. Braunbeck
Ph.D. Thesis, Michigan State Univ., 1976, 158 pp
UM 76-18, 600

Key Words: *Agricultural machinery, Vibration excitation,* Human response, Mathematical models

An hypothesis is proposed in this work which suggests that if intervertebral joint deformations present distinct levels at frequencies encountered in the seat of farm machinery, they will create a fatigue type loading of the intervertebral joint sufficient to induce pain sensations. A lumped parameter dynamic model of the upper torso and head is proposed, whose main objective is to predict lumbar intervertebral joint deformations. The governing differential equations of motion are written for a linear system exposed to sinusoidal small amplitude displacement excitation in the vertical direction through the pelvis. A particular solution is found for the system of 58 second order differential equations that provides an equal number of complex amplitudes of motion, corresponding to each one of the degrees of freedom in the system. The rheological behavior of deformable components of the structure is modeled by means of Kelvin viscoelastic elements. The stiffness and damping coefficients for the axial mode of oscillation are derived from impedance data taken from isolated vertebral units. The model is validated by computing seat to head transmissibility as well as driving point impedance coefficients over the frequency range 5-50 Hz. The transmissibility and impedance curves corresponding to the model closely resemble the experimental curves even though the values differ somewhat.

76-1995
Correlation of Floor Vibration to Human Response
J.R. Shaver
Ctr. for Bldg. Tech., National Bureau of Standards, Washington, D.C., Rept. No. NBS-TN-904, 31 pp (May 1976) (Supersedes Rept. No. NBSIR-75-951, PB-249-094)
Sponsored in part by Dept. of Housing and Urban Dev., Washington, D.C.
PB-253 230/7GA

Key Words: Floors, Vibration excitation, Human response

A new approach to the problem of perceptible floor vibrations is presented predicated on the realization than human activity and human response to this activity are random variables. Techniques for data reduction are discussed, and a detailed description of one approach is given along with the associated computer program. Data from floor vibrations are compared with current criteria for human response to vibration.

ISOLATION

(Also see Nos. 1959, 2017)

76-1996
Oil Compressibility and Polytropic Air Compression Analysis for Oleopneumatic Shock Struts
M.K. Wahi
Boeing Commercial Airplane Co., Renton, WA., J. Aircraft, 13 (7), pp 527-530 (July 1976) 6 figs, 7 refs

Key Words: Shock absorbers, Mathematical models

Various aspects of dynamic design of oleopneumatic landing gear shock absorbers were investigated. A review of available literature shows that effects on shock absorption characteristics due to hydraulic fluid compressibility, gas solubility and its entrainment-in-oil, and the nature of polytropic exponent during the compression stroke are often neglected by the designer. An attempt has been made to establish the importance of these parameters and possible means of representing them as mathematical models. The suggested models are capable of being incorporated into any realistic shock strut dynamics similation.

76-1997
Translatory Shock Absorber for Attitude Sensors
G.L. VonPragenau, I.T. Morgan, Jr. and C.A. Kirby
NASA, Marshall Space Flight Ctr., Huntsville, AL., U.S. Patent 3,952,980, 5 pp (Apr 27, 1976)
N76-22284

Key Words: Shock absorbers, Spacecraft equipment, Attitude control equipment

A translatory shock absorber is provided for mounting an attitude sensor thereon for isolating a sensor from translatory vibrations. The translatory shock absorber includes a hollow block structure formed as one piece to form a parallelogram. The absorber block structure includes a movable top plate for supporting the attitude sensor and a fixed base plate with opposed side plates interposed between. At the junctions of the side plates, and the base and top plates, there are provided grooves which act as flexible hinges for attenuating translatory vibrations. A damping material is supported on a pedestal which is carried on the base plate between the side plates thereof. The top of the damping material rests against the bottom surface of the top plate for eliminating the resonant peaks of vibration.

MATERIAL HANDLING

(See No. 1963)

MECHANICAL

76-1998

Diesel-Powered Heavy-Duty Refrigeration Unit Noise

J.T. Retka

Corad Div., Donaldson Co., Inc., Minneapolis, MN., Rept. No. DOT-TSC-OST-75-53, 50 pp (Jan 1976) PB-250 554

Key Words: Refrigerators, Noise measurement

A series of noise measurements were made on a diesel-powered heavy-duty refrigeration unit. Noise survey information collected included: polar plots of the 'A Weighted' noise levels of the unit under maximum and minimum load conditions; a linear and 'A' weighted acoustical time history of the refrigeration unit noise operating from start-up to load conditions representing both minimum (unloaded) and maximum (loaded) cooling capacity; the determination of the unmuffled refrigeration unit engine exhaust noise level under maximum and minimum load conditions; the determination of the noise contribution, under maximum load conditions, from the refrigeration unit engine exhaust and engine cooling system fan to the overall system noise.

METAL WORKING AND FORMING

76-1999

Identification and Analysis of Machine Tool System Dynamics under Actual Working Conditions Using Time Series Methods

F.A. Burney

Ph.D. Thesis, The University of Wisconsin-Madison, 1976, 221 pp

UM 76-15,981

Key Words: Machine tools, Chatter, Series (mathematics), Mathematical models

The identification and analysis of a machine tool system dynamics under actual working conditions is useful for the purpose of the machine tool chatter control, acceptance testing, and design evaluation. On account of the stochastic and time-dependent nature of the machine tool vibrations, this thesis utilizes a new time series technique called the 'Dynamic Data System (DDS)' for the purpose of such an analysis. Described succinctly, the technique develops a statistically adequate mathematical model of the system under a given condition from the data collected from the system. The data collection, which has to be based on a proper physical understanding of the system, can be performed during the course of its (system's) normal operation. Considerable experimental work is done in this research to monitor and record the cutter-workpiece relative vibration and the cutting force data from a vertical milling machine during the face-milling operations carried out under different cutting conditions. A new type of force transducer is employed for collecting the tangential cutting force signal.

76-2000

Kinetic and Dynamic Effects on the Upper-Bound Loads in Metal-Forming Processes

J. Tirosh and S. Kobayashi

Dept. of Mechanical Engrg., Material Processing and Machine Tool Ctr., Technion-Israel Inst. of Tech., Haifa, Israel, J. Appl. Mech., Trans. ASME, 43 (2), pp 314-318 (June 1976) 4 figs, 14 refs

ASME Paper No. 76-APM-28

Key Words: Metal working

The regular upper-bound approach in metal-forming processes is extended to time-dependent processes. The ultimate goal is to estimate, in an approximate manner, time rate effects such as machine speed and material inertia, on the forming load of time independent materials. The admissible velocity field with associated jumps is used to generate an acceleration flow field and associated flow resistance.

PACKAGE

76-2001

Shock and Vibration Evaluation of ML-8094/199 Tube Container

R.V. Brown
Air Force Packaging Evaluation Agency, Wright-Patterson AFB, OH., Rept. No. DSPT-76-16, 22 pp (May 1976)
AD-A025 147/0GA

Key Words: Shipping containers, Packaging, Vibration tests, Shock tests, Drop tests

The Defense Electronic supply Center reported that excessive damage had been experienced during shipment of ML-8094/199 High Voltage Rectifier tubes from the Connecticut based manufacturer to Peterson Field, Colorado. The main objectives of this study were twofold: (1) Determine if the present pack will protect the tube when subjected to rough handling tests as prescribed by MIL-P-116; and (2) Determine if the pack could be modified to afford increased protection to the tube.

76-2002
Variability of Cushioning Properties of Polyurethane Foams
R.V. Brown
Air Force Packaging Evaluation Agency, Wright-Patterson AFB, OH., Rept. No. DSPT-76-8, 18 pp (Mar 1976)
AD-A022 461/8GA

Key Words: Packaging materials, Polyurethane resins, Foams

The primary objective of this study was to determine the variability in the dynamic cushioning properties of flexible polyurethane foam materials procured from different sources under the requirements of MIL-P-0026514C. A secondary objective was to establish the degree of correlation between the dynamic cushioning properties of polyurethane foam and various material physical properties such as density, static stress characteristics and Indent Load Deflection (ILD) factor. The results of this study show that there is considerable variability in the dynamic cushioning properties of polyurethane foam materials.

PUMPS, TURBINES, FANS, COMPRESSORS

(Also see Nos. 1936, 1961, 1984)

76-2003
Determination and Probabilistic Foundation Forces Resulting from an Unbalanced Turbine
M.L. Boyce and T.J. Kozik
Texas A & M Univ., College Station, TX., ASME Paper No. 76-GT-120

Key Words: Turbines, Machine foundations

This paper considers the problem of the unbalanced rotating turbine as a single degree of freedom system, wherein the principal mode of vibration is a translation in the direction of the machine supports. The distance from the center of mass of the rotating mass to the geometric axis, also known as the effective eccentricity, is modeled as a random variable. The expression for the root mean square response of the rotating machine is derived and related to the statistical analog for the deterministic expression for the foundation force. These results are numerically compared to their equivalent deterministic values.

76-2004
Modal Structure Inferred from Static Far-Field Noise Directivity
A.V. Saule
NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71909; E-8704, 12 pp (1976) (proposed for presentation at 3d Aero-Acoustics Conf., Palo Alto, CA., 20-23 July 1976; sponsored by AIAA)
N76-21207

Key Words: Fans, Turbine components, Noise generation

Turbofan noise directivity calculated for two directivity models was compared with experimental, blade passing frequency data from two fans at 60 and 90 percent speeds. Experimental data indicated similar directivity patterns which were well represented by a single average data curve. Calculated points using the equal amplitude model showed over-prediction near the fan axis and near the 90 degree position.

76-2005
Noise Reduction From the Redesign of a Fan Stage to Minimize Stator Lift Fluctuations
J.H. Dittmar and R.P. Woodward
NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71896; E-8682, 10 pp (1976) (proposed for presentation at 3d Aero-Acoustics Conf., Palo Alto, CA., 20-23 July 1976; sponsored by AIAA)
N76-21206

Key Words: Fans, Noise reduction

An existing fan stage, redesigned to reduce stator lift fluctuations, was acoustically tested for reduced noise generation. The lift fluctuations on the stator were reduced by increasing the stator chord, adjusting incidence angles, and by adjusting the rotor velocity diagrams.

76-2006

Noise Comparisons of Single and Two Stage Demonstrator Fans for Advanced Technology Aircraft

M.F. Heidmann

NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71899; E-8688, 18 pp (1976) N76-23265

Key Words: Fans, Noise reduction

A high-speed single-stage and a low-speed two-stage fan were designed, fabricated, and tested to demonstrate their predicted low noise performance for an advanced 0.85-0.90 cruise Mach number aircraft requiring a 1.8-1.9 pressure ratio fan. Acoustic tests were made with both unsuppressed and suppressed configurations. The two-stage fan demonstrated that quiet fan technology developed for low-speed single-stage fan is applicable to two-stage designs. The unsuppressed high-speed single-stage fan demonstrated that significant reductions in inlet noise can be achieved from the sonic blockage caused by supersonic flow in the rotor blading

76-2007

Altitude Performance of a Low-Noise-Technology Fan in a Turbofan Engine With and Without a Sound Suppressing Nacelle

T.J. Biesiadny, R.E. Grey and M. Abdelwahah

NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-3385; E-8592, 31 pp (Apr 1976) N76-21213

Key Words: Fans, Turbine components, Noise reduction

Test variables were inlet Reynolds number index (0.2 to 0.5), flight Mach number (0.2 to 0.8), and flow distortion (tip radial and combined circumferential - tip radial patterns). Results are limited to fan bypass and overall engine performance. There were no discernible effects of Reynolds number on fan performance. Increasing flight Mach number shifted the fan operating line such that pressure ratio decreased and airflow increased. Inlet flow distortion lowered stall margin.

76-2008

Added Mass of Marine Propellers in Axial Translation

J.E. Brooks

David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD., Rept. No. DTSNRDC-76-0079, 16 pp (Apr 1976) AD-A025 250/2GA

Key Words: Marine propellers, Disks, Resonant frequency

Experimental and theoretical values are compared for the added masses of marine propellers and disks in axial translation. The experimental apparatus and procedure are described in detail, but the theoretical model is only outlined. Values predicted by the theoretical model were 15 to 30 percent smaller than the experimental results, except for the case of a circular disk in broadside motion where the results agreed within 2 percent. The generation of vorticity on the surfaces of the propellers and disks is proposed as a possible explanation for the discrepancies.

RAIL

76-2009

Steering and Dynamic Stability of Railway Vehicles

A.H. Wickens

British Rail Res. and Dev. Division., Derby, England, Vehicle Syst. Dyn., 5 (1-2), pp 15-46 (Aug 1975) 11 figs, 21 refs

Key Words: Railroad vehicles, Dynamic stability, Steering effects

For railway vehicles having coned wheels mounted on solid axles there is a conflict between dynamic stability and steering ability. It is shown that the stiffness and kinematic properties of all possible interwheelset connections are characterized by two properties describing the distortional characteristics of the vehicle in plan. Within this framework, the various possibilities for steered wheelsets are considered, and several past and current proposals are reviewed. Using the linear approach to dynamic stability and curve negotiation the performance of existing and newly proposed configurations is discussed.

76-2010

The Dynamics of Single Track Vehicles

R.S. Sharp

Dept. of Mechanical Engrg., The Univ. of Leeds, Leeds LS2 9JT, England, Vehicle Syst. Dyn., 5 (1-2), pp 67-77 (Aug 1975) 16 refs

Key Words: Monorail railways, Steering effects

The paper contains a brief review of the more subjective aspects of the steering behavior of single track vehicles, a review of the more significant published work in the field, and an assessment of the current state of understanding and likely ways in which further progress can be made. Attention is drawn to the many areas of agreement between theory and practice and to some areas of disagreement. The greatest need now seems to be for the incorporation of more complex tire models into vehicle handling models.

REACTORS

76-2011

A Method for Systematic Interpretation of Dynamic Measurements in a High Temperature Gas-Cooled Reactor

S.-I. Chang

Ph.D, Thesis, The University of Tennessee, 1976, 234 pp

UM 76-17, 720

Key Words: Nuclear reactors, Mathematical models, Parameter identification techniques

This study presents the development and application of a new technique for practical parameter identification of systems whose dynamics are described by up to 110 first order, linear differential and algebraic equations. A partitioned matrix technique was developed for this purpose. This technique which takes advantage of the matrix form of the system equations, constitutes a very efficient analysis algorithm when implemented on the digital computer. The identification procedure is to be used to analyze test results from the Fort St. Vrain high temperature, gas cooled reactor.

RECIPROCATING MACHINE

(Also see No. 1919)

76-2012

Truck Noise III-H. Final Report on the Freightliner Quieted Truck Program

T.D. Hutton, Jr.

Bolt Beranek and Newman, Inc., Cambridge, MA., Rept. No. DOT/TST-76-55, 57 pp (Jan 6, 1976) (prepared in cooperation with Freightliner Corp., Portland, OR., see also PB-246 263)

PB-251 680/5GA

Key Words: Motor trucks, Engine noise, Diesel engines, Noise reduction, Acoustic measurement

This report summarizes the results of Freightliner's research, evaluation, and demonstration of diesel truck noise control efforts for the Quiet Truck Program sponsored by the Department of Transportation's Office of Noise Abatement. A synopsis of each of the seven previous Freightliner/DOT 'Truck Noise 3' reports documenting the various aspects of the program is provided. Significant conclusions are presented from the findings of these reports, along with a number of factors that must be considered to establish a proper perspective for evaluating these findings.

ROAD

(Also see Nos. 1881, 1886, 1913)

76-2013

Stochastic Road Inputs and Vehicle Response

J.D. Robson and C.J. Dodds

Dept. of Mechanical Engineering, Univ. of Glasgow, Scotland, Vehicle Syst. Dyn., 5 (1-2), pp 1-13 (Aug 1975) 37 refs

Key Words: Ground vehicles, Automobiles, Stochastic processes, Road roughness, Spectral analysis

The paper explains the basis of the standard spectral techniques which are available for the description and analysis of stochastic processes, and emphasizes the restrictions implied by their acceptance. Progress towards the present state of the art is indicated by reference to work published over the last 25 years; this work has established that a stationary gaussian stochastic process does provide a satisfactory basic model for a road surface, and it has now reached a state of considerable sophistication. The development of experimental simulation techniques, based on multivariate stochastic process theory, is described and the relationship of such tests to response analysis is explained. There is some discussion of the probable directions of future progress. The presentation is based primarily on the automobile response problem, but many of the techniques described are applicable also to other forms of vehicle.

76-2014

Analysis and Interpretation of Steady-State and Transient Vehicle Response Measurements

N.F. Barter

The Motor Industry Res. Association, Nuneaton, England, Vehicle Syst. Dyn., 5 (1-2), pp 79-103 (Aug 1975) 8 figs, 63 refs

Key Words: Ground vehicles, Steering effects, Periodic response, Transient response

This paper is concerned with the description of the open loop response of road vehicles to steering inputs. The important literature is reviewed for both steady state and transient response behavior. The measures available for steady state response covering the whole range of lateral acceleration are discussed in detail, and sample measured data are presented. It is shown that the important quantities are the effective cornering stiffnesses of the front and rear tires, how they are related, and how they vary with lateral acceleration. Transient response is only considered for the region of linear behavior, where it is seen that a control theory approach is appropriate. A sample set of frequency response curves and step input responses are presented. It is concluded that satisfactory methods of measurement and description are available but that 'desirable' levels cannot yet be firmly specified.

76-2015

Simulation of Directional Behaviour of Road Vehicles

U. Sorgatz

Volkswagenwerk AG, Wolfsburg, Germany, Vehicle Syst. Dyn., 5 (1-2), pp 47-66 (Aug 1975) 12 figs, 35 refs

Key Words: Digital simulation, Ground vehicles

This paper contains a review of simulations of the dynamic behavior of vehicles to directional road planar/inputs.

76-2016

On the Stability in the Sense of Liapunov of a Rubber Tire Vehicle

H.K. Sachs and C.C. Chou

Wayne State Univ., Detroit, MI., J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 180-185 (June 1976) 2 figs, 13 refs

Key Words: Ground vehicles, Stability, Tire characteristics

A qualitative evaluation of the vehicle stability problem is given for the purpose of establishing a measure of the performance limit of automobiles for the imposed conditions of constant speed and fixed steer control.

76-2017

Investigation of Fluidically Controlled Suspension Systems for Tracked Vehicles

W.R. Eberle and M.M. Steele

School of Aeronautics, Astronautics and Engineering Sciences, Purdue Univ., Lafayette, IN., Rept. No. TACOM-TR-12072, 96 pp (Sept 1975)

AD-A022 636/5GA

Key Words: Tracked vehicles, Suspension systems (vehicles), Mathematical models

Thus use of fluidic components in a hydropneumatic suspension system is expected to significantly improve certain performance characteristics of the suspension system. Several candidate variable damping and variable springing systems are discussed. The damping and springing parameters are functions of relative position (between the wheel and the vehicle body), relative velocity, and vertical acceleration of the vehicle body. A mathematical model is derived for each candidate system. A brief performance analysis of selected systems is presented.

ROTORS

76-2018

Unsteady Drag and Dynamic Stall as Simulated in a Varying Freestream

D.L. Kunz

Ph.D. Thesis, Georgia Institute of Technology, 1976, 189 pp

UM 76-16,984

Key Words: Helicopter rotors, Rotary wings, Stalling

The objectives of this investigation were to find out to what extent streamwise, simple harmonic velocity perturbations in the freestream affect dynamic stall and unsteady drag.

76-2019

The Application of Gas- and Oil-Lubricated Foil Bearings for the ERDA/Chrysler Automotive Gas Turbine Engine

S. Gray, N. Sparks and J. McCormick

Mechanical Technology, Inc., Latham, NY., ASME Paper No. 76-GT-115

Key Words: Rotor-bearing systems

A design study has been made of a resilient hydrodynamic foil bearing support system for a 58,500-rpm automotive gas turbine rotor utilizing an air-lubricated journal bearing at the hot turbine end and an oil-lubricated journal and thrust bearing at the compressor end. The paper includes a review of earlier engine rotor/bearing systems and lists the potential advantages of the foil bearings. Design analysis of the bearings and rotordynamics is given including critical speeds, rotor unbalance response, bearing performance, and temperature distributions to confirm the feasibility.

76-2020

An Empirical Design Procedure for Shafts with Fatigue Loadings

J.D. Grounds

Darcom Intern Training Center, Texarkana, TX., Rept. No. DARCOM-ITC-02-08-76-017, 40 pp (Apr 1976)

AD-A024 785/8GA

Key Words: Shafts, Fatigue strength, Design techniques

This report presents a method of designing rotating shafts subjected to combined fatigue loads. In the past, the fatigue strength, a material property necessary for design, has been determined for axial, bending, and torsional loads independently. A general approach to design with combined loads requires a fatigue strength that does not depend on the type of loading. Measured differences in the fatigue strengths are attributed to the size of a shaft. By developing correction factors to be used on the applied bending and torsional loads, the axial fatigue strength can be used for combined loads.

SATELLITE

(See No. 1931)

SPACECRAFT

(Also see Nos. 1895, 1896, 1897, 1967, 1997)

76-2021

Effects of Unsymmetrical Stability Derivative Characteristics on Reentry Vehicle Transient Angular Motion

A.E. Hodapp, Jr.

Sandia Labs., Albuquerque, NM., Rept. No. SAND-75-0252, 37 pp (Sept 1975)

N76-23174

Key Words: Reentry vehicles, Stability analysis

Analytical results, numerical results, and results of digital flight simulations are presented for an investigation of the effects that unsymmetrical stability derivative characteristics have on the transient angular motion of slender rolling reentry vehicles. It is shown that in addition to changing the motion patterns, damping, and frequency relative to those for symmetrical missiles, unsymmetrical stability derivatives can cause an exponential growth of the transient angle of attack for flight conditions within the resonance region.

76-2022

Analysis of Structural Dynamic Data from Skylab. Volume 1: Technical Discussion

L. Demchak and H. Harcrow

Martin Marietta Corp., Denver, CO., Rept. No. NASA-CR-144285; MCR-76-179-Vol-1, 222 pp (Mar 1976)

N76-22269

Key Words: Spacecraft

A compendium of Skylab structural dynamics analytical and test programs is presented. These programs are assessed to identify lessons learned from the structural dynamic prediction effort and to provide guidelines for future analysts and program managers of complex spacecraft systems. It is a synopsis of the structural dynamic effort performed under the Skylab Integration contract and specifically covers the development, utilization, and correlation of Skylab Dynamic Orbital Models.

76-2023

Analysis of Structural Dynamic Data from Skylab. Volume 2: Skylab Analytical and Test Model Data

L. Demchak and H. Harcrow

Martin Marietta Corp., Denver, CO., Rept. No. NASA-CR-144286; MCR-76-179-Vol-2, 216 pp (Mar 1976)

N76-22270

Key Words: Spacecraft, Mode shapes

The orbital configuration test modal data, analytical test correlation modal data, and analytical flight configuration modal data are presented. Tables showing the generalized mass contributions (GMCs) for each of the thirty tests modes are given along with the two dimensional mode shape plots and tables of GMCs for the test correlated analytical modes. The two dimensional mode shape plots for the analytical modes and uncoupled and coupled modes of the orbital flight configuration at three development phases of the model are included.

76-2024

Shuttle On-Pad Ground Wind Loads

A.D. Devers, E. Simon, T.E. Blejwas, and A.C. Park

Martin Marietta Corp., Denver, CO., Rept. No. NASA-CR-144290; MCR-75-446, 285 pp (Apr 1976)

N76-23623

Key Words: Spacecraft, Wind-induced excitation, Computer programs, Towers

A digital computer program system capability was developed which includes: (1) the ability to generate both static and dynamic load components and resultants for all wind azimuths due to drag, gusts and/or wind induced oscillations: (2) the ability to establish both static and dynamic components and resultant deflections versus vehicle station for the saperate shuttle system components; (3) the ability to analyze the dynamic loads and responses resulting from Orbiter ignition/shutdown (rebound phenomena); and (4) the ability to combine structural loads and deflections from different load sources.

76-2025

Coupled Base Motion Response Analysis of Payload Structural Systems

A.D. Devers, H. Harcrow and A.R. Kukreti

College of Engrg. and Applied Science, Colorado Univ., Boulder, CO., Rept. No. NASA-CR-144291; UCCE-75-2, 113 pp (Apr 1976)

N76-23624

Key Words: Coupled response, Component mode analysis, Spacecraft

Coupled base motion response analysis of payload structural systems is discussed. A systems analysis program is described which by component analysis structural transient response analyses can be completed. The program presents a proven technique, used initially on the Skylab program, which is designed to reduce cost and schedule time on detail structural analyses of structural payload systems. Base motion procedures are employed where critical segments of complex structural systems or components may be analyzed for various load conditions without having to re-establish the entire structural system coupled model properties. The transient response characteristics of a complex structural system are used as a basis for evaluating the transient response of a similar system.

76-2026

Analytical Prediction of Motor Component Vibrations Driven by Acoustic Combustion Instability

F.R. Jensen

Hercules Inc., Systems Group, Wilmington, DE., Rept. No. AFRPL-TR-76-11, 656 pp (Feb 1976)

AD-A025 261/9GA

Key Words: Solid propellant rocket engines, Combustion noise, Oscillation, Finite element technique, Computer programs

A detailed investigation has been conducted on the structural dynamic response of solid rocket motors. The study was particularly concerned with estimating the structural response to unstable acoustic combustion oscillations that often occur in solid motors during motor firing time. Detailed finite element analyses were performed on the Poseidon C-3 second stage motor and on the Minuteman III third stage motor using a NASTRAN computer program. In addition, the response of an inert second stage Poseidon C-3 motor to internal acoustic excitation was measured during an experimental task.

76-2027

Suspension for Missile Equipment: Measurement of the Dynamic Characteristics of Viscoelastic Materials Utilizable as Dampers

J. Moriceau

Laboratoire de Recherches Balistiques et Aerodynamiques, Vernon, France, Service Environnement et Metrologie, Rept. No. LRBA-E-1-300-1/SEM, 90 pp (June 1975)

(In French)

N76-22552

Key Words: Spacecraft equipment, Equipment mounts, Viscoelastic damping

Tests were carried out to determine the dynamic stiffness and damping of some viscoelastic materials, in order to develop a catalog of viscoelastic materials to be used in shock or vibration damping systems including not only their chemical and mechanical properties but also their dynamic characteristics as function of some parameters. The principles of the method for the measurement of dynamic characteristics are presented and results discussed. The influence of temperature and specimen geometry is evidenced. The use of polyurethane elastomers in damping systems, over rubber and polyester foams, is emphasized.

STRUCTURAL

(Also see No. 1898)

76-2028

Overturning and Sliding Analysis of Reinforced Concrete Protective Structures

W. Stea, S. Weissman, N. Dobbs and P. Price

Ammann and Whitney, NY., Rept. No. PA-TR-4921, 279 pp (Feb 1976)

AD-A022 619/1GA

Key Words: Protective shelters, Reinforced concrete, Blast resistant structures, Interaction: soil-structure, Computer programs

This report presents design procedures and the computer program written to implement them for determining the gross motions of protective structures subjected to blast effects of high explosive detonations. These procedures are intended to supplement the design methods of the tri-service design manual 'Structures to Resist the Effects of Accidental Explosions' (TM 5-1300). The material presented includes dynamic analysis techniques for determining the gross motions of the structure on its supporting soil, methods for computing the time history of the blast load on the structure, and criteria and procedures for designing the foundation of the structure. A system of classification of various soils is given together with a tabulation of critical soil properties.

TURBOMACHINERY

(Also see Nos. 1935, 1937)

76-2029

Experiments on Oil-Film Dampers for Turbomachinery

M. Botman

Pratt & Whitney Aircraft of Canada, Ltd., Longueull, Quebec, Canada, J. Engr. Power, Trans. ASME, 98 (3), pp 393-400 (July 1976) 15 figs, 8 refs

ASME Paper No. 75-WA/GT-19

Key Words: Fluid-film damping, Turbomachinery

Oil-film dampers are used in turbomachinery to suppress undesirable shaft dynamic responses. They are located at the nonrotating outer race of selected main bearings. A rig is described that was designed to evaluate the effect of damper geometry on the rotor responses. Typical test results are shown which indicate that cavitation limits the maximum speed at which dampers should be used.

76-2030

Methods of Dynamic Measurements in Turbomachines

R. Larguier and A. DeSievers

Royal Aircraft Establishment, Farnborough, England, Rept. No. RAE-Lib-Trans-1835; BR51462; ONERA-TP-1403-(1974), 26 pp (Jan 1976) (Transl. into English from L'Aeronautique et L'Astronautique (France), 46, pp 9-18 (1974); ONERA-TP-1403-(1974)

N76-22542

Key Words: Turbomachinery, Measurement techniques

The work at ONERA on dynamic measurements in turbomachines, which extends from incompressible to supersonic flow is reported. Data on surface pressures on moving blades and on the external casing, opposite the rotor, and on determination of the wake by pressure sensor and hot wire are presented.

76-2031

Determination of the Time-Averaged Pressures in Strongly Fluctuating Flows and Especially in Turbo-Machines

H. Weyer

Royal Aircraft Establishment, Farnborough, England, Rept. No. RAE-Lib-Trans-1850; DLR-FB-74-34, 145 pp (Jan 1976) (Transl. into English from Deutsche Luft- und Raumfahrt, Rept. No. DLR-FB-74-34)

N76-22543

Key Words: Turbomachinery, Dynamic response, Measuring instruments

The problems of measuring pressure are studied for strongly fluctuating flow - for example, in turbomachines - with particular regard to the determination of clearly defined average pressures. A detailed description is given of the operating principles of three new procedures for determining the actual time averages of pressure fluctuations of high frequency and amplitude and also of the construction of the corresponding measuring devices. Laboratory testing of these procedures is reported using a newly developed calibration device that generates defined pressure fluctuations, and initial tests of the measuring devices in turbocompressors are described.

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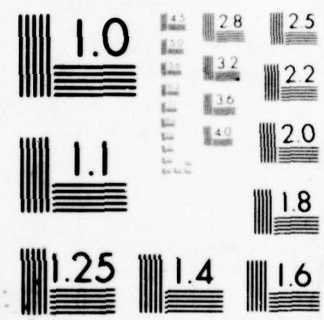

MICROCOPY RESOLUTION TEST CHART
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				154	155		857	618	1379
					275				
					305				
					365				
					945				
					1955				

Fluid-Film Bearings

1870					1585		1707		

Fluid-Film Damping

80					1705				2029

Fluid Hammer

					105				

Fluid-Induced Excitation

60	31		13	74	105	86	17	18	119
610	101		103	364	365	226	137	548	229
1030	631		113	544	555	836	227	618	849
	1381		1133	704	835	1446	737	848	1379
	1581			1604	1215	1596	1017	858	1549
	1901				1445	1806	1597	968	1599
					1605			1018	1939
					1675			1678	1949
					1685			1808	

Fluid-Induced Vibrations

		112	73	394		106		118	

Fluid Mass

							1377		

Fluids

								228	

Flutter

240	331	282	283	284	425	256	417	418	419
280	421	422	423	354	565	566	627	828	629
390	561	562	563	424	665	606	847	1048	1049
420	681	1022	633	554		1046	1047	1108	1209
440	1331	1272	1023	564		1296	1387	1118	1969
850	1601	1472	1473	664		1506	1917	1128	
1970	1971	1572		884				1388	
	1801	1972		1234				1638	
				1954				1988	

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Moving Loads

310		142		374	75	1576	1577	1578	819
		862		744					1819
				1134					

Mufflers

		452	543						1439
			603						

Multi-Beam Systems

	451					836			

Multidegree of Freedom Systems

	21	762		334	1505		57	1118	969
					1725				

Multifrequency Oscillations

					5				

Multistory Buildings

1990	901	902		1064	1065		1837	1838	1269
	1731	1482							

Musical Instruments

70					1795				

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Nacelles

			403						

NASTRAN (Computer Programs)

540		492	493		495	496	497	498	499
500					615		517	538	
					1315				

Natural Frequencies

130	251	22	123	84	85	106	307	278	109
160	271	122	133	114	125	426	687	418	519
540	1031	442	153	234	675	586	817	868	1119
550	1111	1842	303	864	845	1016	857	948	1329
1330	1231		553	1224	865	1526	1447	1238	1459
1890	1351		613	1724	1005	1816	1657	1328	1619
	1411		643		1025		1787	1418	1809
	1551		943		1315		1817	1948	
	1711		1123		1415				
			1323		1625				
			1803		1815				

Nature Parameter

			1483						

Newton-Raphson Method

							757		

Noise Acoustic Measurement

		722							

Noise Barriers

		1912	1633	874	875	926			
				1034		1466			

Noise Control

340	341			1884			637	638	

Noise Generation

740	81	202	353	604	455	456	937	28	219
1030	201	302	453	1964	715	466	1597	178	739
1640	281	572	463	2004	775	776	1697	778	939
1670	461	802	623		1055	1426		1528	1149
1680	1221	1262	1283		1655	1476		1668	1489
	1291	1312	1563		1675	1676		1858	1599
	1381	1682	1683						1669
	1671	1892	1893						1679
	1681	1852							

Noise Measurement

350	371	332	523	404	195	466	197	168	349
1260	411	402	593	594	405	1056	1527	698	379
	721	712	803	1074	925			768	469
	1571	1562	1073	1174				778	569
		882		1494				918	989
								1258	1259
								1518	1629
								1688	
								1978	
								1998	

Noise Prediction

	731	732	203		1055	1076			1859
	891		623			1346			
	1291		733						
	1641								

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Noise Reduction

180	171	172	203	174	35	166	197	198	139
260	201	202	403	194	195	296	397	388	199
470	471	412	443	204	495	306	407	398	389
640	571	452	453	264	695	406	727	548	399
700	731	462	543	344	875	636	837	588	639
730	771	472	573	414	1035	796	877	728	729
830	1011	572	603	484	1255	926	927	768	739
920	1071	712	623	694	1475	1136	1037	838	839
940	1291	732	693	874	1665	1666	1297	878	879
1100	1381	892	733	1054	1885	1886	1467	928	1079
1230	1521	1002	873	1254	1945	1976	1477	1058	1099
1250	1961	1012	893	1524	2005	2006	1487	1628	1489
1280	1981	1072	913	1984			1627	1868	1629
1290		1292	1053				1677		1669
1960		1602	1523				1687		1719
1980		1962	1643				2007		1959
		1982	1943						1869
		2012	1963						
		1852	1983						

Noise (Sound)

710									

Noise Source Identification

740		1052	1213		1095	1656	1977		959
1530			1343			1856			
1950			1643						

Noise Tolerance

		292			135				
		1652			1485				

Nondestructive Testing

				244		536	367		
				804					

Nondestructive Testing Technique

		1782							

Nondestructive Tests

	1781		743						

Nonlinear Analysis

760	761			334		756			

Nonlinear Programming

1140									

Nonlinear Response

1080		62	3	754		276	117	538	9
1930							1457	1798	

Nonlinear Structures

	181								

Nonlinear Systems

950		1322			1515	96		488	
1320					1725			1358	

Nonlinear Theories

1460		762			1505				19

Nonparametric Identification

							897		

Non-Proportional Damping

				1744					

Normal Mode Method

						126			

Normal Modes

1330	961			124	625			608	
				614	1925				
				1024					

Nozzles

570	1221		623					778	199
			1013						1599

Nuclear Explosion Damage

						216			
						286			

Nuclear Explosion Effects

360		52	53						

Nuclear Explosions

	781	782							

Nuclear Fuel Elements

	631		73	1684	1685		227		9
			313						

Nuclear Power Plants

170	141	212	213	104		146	267	1318	169
1840	211	972	1693			266			1189
1860	1491	1732				1186			
	1761	1862							
	1861								

Nuclear Reaction Components

		922							9

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Ray-Mode Analysis

	191								

Receptance Method

			1453	1454					

Reciprocal Measurement

					65				

Reciprocating Engines

1690	1691						1077	308	

Recording Instruments

	991			534					

Rectangular Bodies

	1941	1942	1943						
	1771								

Rectangular Plates

	1231	1232	1233	274	1815	1026	1027	858	
								1948	

Redundant Systems

		972							

Re-Entry Vehicles

890	2021							378	
								788	

Refrigerators

								1998	

Regulations

340	341			1054		166	167		1519
				1254		636			

Reinforced Beams

							657		

Reinforced Concrete

900		1752	773	844	1835	286	897	898	1269
1740				1834		1836	1117	2028	
							1987	1828	

Reinforced Materials

	791								

Reinforced Plates

					865				

Reinforced Shells

			1033			686			

Reliability

		972			725	1516			

Research Facilities

	531								

Resonance

1810									

Resonance Tests

1780				794					

Resonant Frequencies

	1621	1572	1873	1404	1535			2008	1579
	1771				1855				

Resonators

		952	953		15				

Response Limiting

							37		

Response Spectra

40	1721		213					208	
			1693						

Reverberation Chambers

1390				1414	25				
				1514	1775				
				1774					

Reverberation Systems

									649

Reviews

1140	1131	342	1133	1004	345	176	297	688	689
	1141	1132	1143	1134	1115	1136	1137	768	1139
	1281	1142	1183	1144	1135	1726	1177	798	1929
	1341			1864				1138	

Ride Dynamics

320	321	1302	323	324	1175	1176	317	318	529
1340	1341	1362	1363	1364	1365	1336	1177	718	1339
1370	1371	1372	1373			1366	1337	1368	1369
							1367		1779

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Sound Transmission

840	131	1552	543	964	65	696	1947		399
1350	191		963	1214	1035	766	1977		1219
1380	1431				1345	1036	1807		1229
1760						1066			1439
									1809

Sound Transmission Loss

1350			1833	1034				1028	1199

Sound Wave Attenuation

1440									

Sound Waves

380	351	542	543	24	55	696	547	1428	269
		1892		1154	715	846			1349
						1486			

Spacecraft

720	751	942	943	944	985	336	37	618	619
1110	1111	2022	1403	1114	1315	1316	617		1109
1500	1501		2023	1394	1395		747		1499
1560				2024	2025		1107		
							1407		
							1717		

Spacecraft Antennas

1180									

Spacecraft Components

	331				595		477	498	749
					1105		1377	748	1799
					1715			1718	

Spacecraft Equipment

	1931				1895	1896	1897		
							1997		
							2027		

Spacecraft Equipment Response

1160	1161	1162						1158	509
									1159

Space Stations

500	161			1104	1105	1106	1497	1108	479
					1715	1716			499
									1719

Specifications

					1335	1336	197		
							477		

Spectra

			783						

Spectral Analysis

			2013						

Spectral Energy Distribution

1200	1841	1832						38	1799
								1188	

Spectrum Analysis

1760	1721		1353	1434	605		207		689
			1393		1265		1227		1379
							1547		

Spectrum Analyzers

			1393		1145				

Spheres

200							1827		1459

Spherical Shells

	1611		43	124	685	856		118	
			1823	1614	1825	1246			
				1824		1826			

Spherical Waves

			33						759

Springs

								1248	

Squeeze Film Bearings

80	1591	612					77		1899
1590		672							
1900									

Squeeze Film Dampers

	151	152							

Stability

150	11	12	13	664	265	76	337	658	79
1810	51	442	703	704	665	956	1147	828	919
	671	1042	763	884	885	1276	1707	1128	1209
	761		863	934	955	2016		1148	
	1281			954	985			1408	
	1901			1114	1215				
				1554	1245				

Stability Analyses

1130	1331	1332		514	585	156	157	628	
	2021			764	1125		1127		
				1324					

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CIVIL ENGINEERING (NEW YORK) ASCE PUBLICATIONS OFFICE 345 E. 45TH ST., UNITED ENGINEERING CENTER, NEW YORK, N.Y. 10017	Civ. Engr. (N.Y.)
CLOSED LOOP MIT SYSTEMS CORP. P.O. BOX 24012 MINNEAPOLIS, MINN. 55424	Closed Loop
COMPUTERS AND STRUCTURES PERGAMON PRESS INC., MAXWELL HOUSE, FAIRVIEW PARK, ELMSFORD, NEW YORK 10523	Computers and Struc.
DESIGN NEWS CAHNERS PUBLISHING CO., INC. 221 COLUMBUS AVE. BOSTON, MASS. 02116	Design News
DIESEL AND GAS TURBINE PROGRESS DIESEL ENGINES, INC. P.O. BOX 7406 MILWAUKEE, WISC. 53213	Diesel and Gas Turbine Progress
ENGINEERING MATERIALS AND DESIGN IPC INDUSTRIAL PRESS LTD., 33-40 BOWLING GREEN LANE, LONDON EC1R, ENGLAND	Engr. Matl. Des.
ENVIRONMENTAL QUARTERLY ENVIRONMENTAL PUBLICATIONS, INC., 252-46 LEEDS RD., LITTLE NECK, N.Y. 11362	Environ. Quart.
ENVIRONMENTAL SCIENCE AND TECHNOLOGY AMERICAN CHEMICAL SOCIETY 1155 16TH ST., N.W. WASHINGTON, D.C. 20036	Environ. Sci. Tech.
EXPERIMENTAL MECHANICS SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, 21 BRIDGE SQ., WESTPORT, CONN. 06880	Exptl. Mech.
FORSCHUNG IM INGENIEURWESEN VEREIN DEUTSCHER INGENIEUR, GMBH POSTFACH 1139, GRAF-RECKE STR. 84, 4 DUESSELDORF 1, GERMANY	Forsch. Ingenieurw.
GEOTECHNIQUE INSTITUTION OF CIVIL ENGINEERS GREAT GEORGE ST. 7 WESTMINSTER, LONDON, SWIP 3AA ENGLAND	Geotech.
HIGH-SPEED GROUND TRANSPORTATION JOURNAL HIGH-SPEED GROUND TRANSPORTATION JOURNAL, P.O. BOX 4824, DUKE STATION, DURHAM, N.C. 27706	High-Speed Ground Transp. J.
IBM JOURNAL OF RESEARCH AND DEVELOPMENT INTERNATIONAL BUSINESS MACHINES CORP., ARMONK, N.Y. 10504	IBM J. Res. Dev.
ICP QUARTERLY INTERNATIONAL COMPUTER PROGRAM, INC., 2611 EAST 46TH ST., INDIANAPOLIS, IND.	ICP Quart.

PUBLICATION AND ADDRESS	ABBREVIATION
INDUSTRIAL RESEARCH DUN-DONNELLEY PUBLISHING CORP. 222 S. RIVERSIDE PLAZA CHICAGO, ILL. 60606	Indus. Res.
INGENIEUR-ARCHIV SPRINGER-VERLAG NEW YORK INC., 175 FIFTH AVE., NEW YORK, N.Y. 10010	Ing. Arch.
INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS INSTITUTION OF MECHANICAL ENGINEERS 1 BIRDCAGE WALK, WESTMINSTER, LONDON SW1, ENGLAND	Instn. Mech. Engr. Proc.
INSTITUTION OF NAVAL ARCHITECTS, TRANSACTIONS	Instn. Naval Arch., Trans
INSTRUMENTATION HONEYWELL, INC. FORT WASHINGTON, PA. 19034	Instr.
INTERNATIONAL CONGRESS ON ACOUSTICS	Intl. Cong. Acoust.
INTERNATIONAL JOURNAL OF CONTROL TAYLOR AND FRANCIS LTD. 10-14 MACKLIN ST. LONDON WC2B 5NF, ENGLAND	Intl. J. Control
INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS JOHN WILEY AND SONS, LTD., 605 THIRD AVE., NEW YORK, N.Y. 10016	Intl. J. Earthquake Engr. Struc. Dynam.
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Intl. J. Engr. Sci.
INTERNATIONAL JOURNAL OF FRACTURE NOORDHOFF INTERNATIONAL PUBLISHING CO. P.O. BOX 26, LEIDEN NETHERLANDS	Intl. J. Fract.
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Intl. J. Mech. Tool Des. Res.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Intl. J. Mech. Sci.
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Intl. J. Nonlinear Mech.
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING JOHN WILEY AND SONS, LTD., 605 THIRD AVE., NEW YORK, N.Y. 10016	Intl. J. Numer. Methods Engr.
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	

PUBLICATION AND ADDRESS	ABBREVIATION
ISRAEL JOURNAL OF TECHNOLOGY WEIZMANN SCIENCE PRESS OF ISRAEL, BOX 801, JERUSALEM, ISRAEL	Israel J. Tech.
JOURNAL DE MECANIQUE GAUTHIER-VILLARS, 55 QUAI DES GRANDS AUGUSTINES, PARIS 6, FRANCE	J. de Mecanique
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA AMERICAN INSTITUTE OF PHYSICS, 335 E. 45TH ST., NEW YORK, N.Y. 10010	J. Acoust. Soc. Amer.
JOURNAL OF AIRCRAFT AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, 1290 AVE. AMERICAS, NEW YORK, N.Y. 10019	J. Aircraft
JOURNAL OF THE AMERICAN CONCRETE INSTITUTE AMERICAN CONCRETE INSTITUTE P.O. BOX 4754, REDFORD STATION, DETROIT, MICH. 48219	J. Amer. Concrete Inst.
JOURNAL OF THE AMERICAN HELICOPTER SOCIETY AMERICAN HELICOPTER SOCIETY, INC., 30 E. 42ND ST., NEW YORK, N.Y. 10017	J. Amer. Helicopter Soc.
JOURNAL OF THE AUDIO ENGINEERING SOCIETY AUDIO ENGINEERING SOCIETY, 104 LIBERTY ST., UTICA, N.Y. 13502	J. Audio Engr. Soc.
JOURNAL OF AUTOMOTIVE ENGINEERING TWO PENNSYLVANIA PLAZA NEW YORK, N.Y. 10001	J. Automot. Engr.
JOURNAL OF COMPOSITE MATERIALS TECHNOMIC PUBLISHING CO., INC. 750 SUMMER ST., STAMFORD, CONN. 06901	J. Composite Matl.
JOURNAL OF ENGINEERING MATHEMATICS NOORDHOFF INTERNATIONAL PUBLISHING CO. P.O. BOX 26, LEIDEN NETHERLANDS	J. Engr. Math.
JOURNAL OF ENVIRONMENTAL SCIENCES INSTITUTE OF ENFIRONMENTAL SCIENCES, 940 E. NORTHWEST HIGHWAY, MT. PROSPECT, ILL. 60056	J. Environ. Sci.
JOURNAL OF FLUID MECHANICS CAMBRIDGE UNIVERSITY PRESS, 32 E. 57TH ST., NEW YORK, N.Y. 10022	J. Fluid Mech.
JOURNAL OF THE FRANKLIN INSTITUTE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, PHILADELPHIA, PA 19103	J. Franklin Inst.
JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA SCIENCE HOUSE, GLOUCTER AND ESSEX ST. STONEY, AUSTRALIA 2000	J. Instn. Engr., Australia
JOURNAL OF THE INSTITUTION OF ENGINEERS (INDIA), MECHANICAL ENGINEERING DIVISION INSTITUTION OF ENGINEERS (INDIA), 8 GOKHALE RD., CALCUTTA 20, INDIA	J. Instn. Engr. (India), Mech. Engr. Div.

PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF MECHANICAL ENGINEERING SCIENCE INSTITUTION OF MECHANICAL ENGINEERS, 1 BIRDCAGE WALK, WESTMINSTER, LONDON SW1, ENGLAND	J. Mech. Engr. Sci.
JOURNAL OF MECHANICAL LABORATORY OF JAPAN (English Edition) THE GOVERNMENT MECHANICAL LAB., AGENCY OF INDUSTRIAL SCIENCE AND TECHNOLOGY, 4-12 IGUSA SUGINAMI-KU, TOKYO, JAPAN	J. Mech. Lab. Japan
JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST. NEW YORK, N.Y. 11101	J. Mech. Phys. Solids
JOURNAL OF PHYSICS E. (SCIENTIFIC INSTRUMENTS) AMERICAN INSTITUTE OF PHYSICS, 335 E. 45TH ST., NEW YORK, N.Y. 10017	J. Phys. E. (Sci. Instr.)
JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C, ENGINEERING AND INSTRUMENTATION SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE WASHINGTON, D.C. 20402	J. Res. Natl. Bur. Std. Sect. C., Engr. Instr.
JOURNAL OF SHIP RESEARCH SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, 20TH AND NORTHHAMPTON ST., EASTON, PA.	J. Ship Res.
JOURNAL OF THE SOCIETY OF ENVIRONMENTAL ENGINEERS THE MODING PRESS LTD., 6 CONDUIT ST., LONDON W1R9TG, ENGLAND	J. Soc. Environ. Engr.
JOURNAL OF SOUND AND VIBRATION ACADEMIC PRESS, 111 FIFTH AVE., NEW YORK, N.Y. 10019	J. Sound Vib.
JOURNAL OF SPACECRAFT AND ROCKETS AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, 1290 AVE. AMERICAS, NEW YORK, N.Y. 10019	J. Spacecraft and Rockets
JOURNAL OF TESTING AND EVALUATION AMERICAN SOCIETY FOR TESTING & MATERIALS 1916 RACE ST. PHILADELPHIA, PA. 19103	J. Test Eval.
JPL QUARTERLY TECHNICAL REVIEW JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE TECHNOLOGY, 4800 OAK GROVE DRIVE, PASADENA, CALIF. 91103	JPL Quart. Tech. Rev.
LUBRICATION ENGINEERING AMERICAN SOCIETY OF LUBRICATION ENGINEERS, 838 BUSSE HIGHWAY, PARK RIDGE, ILL. 60068	Lubric. Engr.
MACHINE DESIGN PENTON PUBLISHING CO., PENTON BLDG. CLEVELAND, OHIO 44113	Mech. Des.
MASCHINEBAUTECHNIK VEB VERLAG TECHNIK, ORANIENBURGER STR. 13/14, 102 BERLIN, E. GERMANY	Maschinenbautechnik
MECANIQUE APPLIQUEE EDITIONS DE L'ACADEMIE DE LA REPUBLIQUE SOCIALISTE DE ROUMANIE 3 BIS, STR. GUTENBERG, BUCAREST, ROMANIA	Mecanique Appliquee
MEASUREMENTS AND DATA MEASUREMENTS AND DATA CORP. 1687 WASHINGTON RD. PITTSBURGH, PA. 15228	Meas. and Data
MECCANICA PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Meccanica
MECHANICAL ENGINEERING AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 345 E. 47TH ST., NEW YORK, N.Y. 10017	Mech. Engr.
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY KYOTO UNIVERSITY, KYOTO, JAPAN	Mem. Fac. Engr., Kyoto Univ.
MEMOIRES OF THE FACULTY OF ENGINEERING, NAGOYA UNIVERSITY LIBRARY, NAGOYA UNIVERSITY THE FACULTY OF ENGINEERING, FURO-CHO, CHIKUSA-KU, NAGOYA, JAPAN	Mem. Fac. Engr., Nagoya Univ.
MESURES, REGULATION, AUTOMATISME ILIFFE - NTP, INC. 300 E. 42ND ST., NEW YORK, N.Y. 10017	Mes. Regul. Automat.
MIDWESTERN CONFERENCE ON SOLID MECHANICS, PROCEEDINGS	Midw. Conf. Solid Mech., Proc.
MTZ MOTORTECHNISCHE ZEITSCHRIFT FRANCKH'SCHE VERLAGSHANDLUNG 7 STUTTGART 1, PFIZERSTRASSE 5-7, GERMANY	MTZ Motortech. Z.
NATIONAL RESEARCH COUNCIL OF CANADA, DIVISION OF BUILDING RESEARCH, BIBLIOGRAPHY	Natl. Res. Council Div. Bldg. Res. Bibliogr.
NAVAL ENGINEERS JOURNAL AMERICAN SOCIETY OF NAVAL ENGINEERS, INC., SUITE 507 CONTINENTAL BLDG., 1012 14TH ST., N.W., WASHINGTON, D.C. 20005	Naval Engr. J.
NEW ZEALAND ENGINEERING TECHNICAL PUBLICATIONS LTD., C.P.O. 3047, WELLINGTON, NEW ZEALAND	N.Z.Engr.
NOISE CONTROL AND VIBRATION REDUCTION TRADE AND TECHNICAL PRESS LTD., CROWN HOUSE, MORDEN, SURREY, ENGLAND	Noise Control and Fib. Reduction
NOISE CONTROL ENGINEERING RAY W. HERRICK LABS. PURDUE UNIV. WEST LAFAYETTE, IND. 47907	Noise Control Engr.

PUBLICATION AND ADDRESS	ABBREVIATION
NUCLEAR ENGINEERING AND DESIGN NORTH HOLLAND PUBLISHING CO., P.O. BOX 3489 AMSTERDAM, THE NETHERLANDS	Nucl. Engr. Des.
OIL AND GAS J. THE PETROLEUM PUBLISHING CO. 211 S. CHEYENNE TULSA, OKLA. 74101	Oil and Gas J.
PACKAGE ENGINEERING PACKAGE ENGINEERING 5 S. WABASH AVE., CHICAGO, ILL. 60603	Package Engr.
POLISH ACADEMY OF SCIENCES, INSTITUTE OF FUNDAMENTAL TECHNICAL RESEARCH PROCEEDINGS OF VIBRATION PROBLEMS INSTYTUT PODSTAWOWYCH PROBLEMOW, TECHNIKI PAN, WARSAW UI. SWIETOKRZYSKA 21, WARSAW, POLAND	Pol. Acad. Sci., Inst. Fund. Tech. Res., Proc. Vib. Probl.
POWER TRANSMISSION DESIGN INDUSTRIAL PUBLISHING CO., DIVISION OF PITTWAY CORP., 812 HURON RD., CLEVELAND, OHIO 44113	Power Transm. Des.
PROCEEDINGS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS PUBLICATIONS OFFICE, ASCE, UNITED ENGINEERING CENTER, 345 E. 47TH ST., NEW YORK, N.Y. 10017	
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JOURNAL OF THE ENGINEERING MECHANICS DIVISION	ASCE J. Engr. Mech. Div.
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JOURNAL OF THE HYDRAULICS DIVISION	ASCE J. Hydraul. Div.
JOURNAL OF THE GEOTECHNICAL ENGINEERING DIVISION	ASCE J. Geotech. Engr. Div.
JOURNAL OF THE IRRIGATION AND DRAINAGE DIVISION	ASCE J. Irrig. Drain. Div.
JOURNAL OF THE POWER DIVISION	ASCE J. Power Div.
JOURNAL OF THE SANITARY ENGINEERING DIVISION	ASCE J. Sanit. Div.
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JOURNAL OF THE STRUCTURAL DIVISION	ASCE J. Struc. Div.
JOURNAL OF THE WATERWAYS, HARBORS, AND COASTAL ENGINEERING DIVISION	ASCE J. Waterways Harbors and Coastal Engr. Div.
TRANSPORTATION ENGINEERING JOURNAL	ASCE Transp. Engr. J.
PROCEEDINGS OF THE INSTITUTE OF ENVIRONMENTAL SCIENCES INSTITUTE OF ENVIRONMENTAL SCIENCES 940 E. NORTHWEST HIGHWAY MT. PROSPECT, ILL. 60056	Proc. Inst. Environ. Sci.
PROCESS DESIGN CAHNERS PUBLISHING CO., INC. 221 COLUMBUS AVE. BOSTON, MASS. 02116	Process Des.
PRODUCT ENGINEERING (NEW YORK) MC GRAW-HILL BOOK CO., 330 W. 42ND ST., NEW YORK, N.Y.	Product Engr. (N.Y.)
QUARTERLY OF APPLIED MATHEMATICS AMERICAN MATHEMATICAL SOCIETY, P.O. BOX 6248, PROVIDENCE, R. I. 02904	Quart. Appl. Math.
QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS OXFORD UNIVERSITY PRESS, PRESS RD., NEASDEN, LONDON NW10, ENGLAND	Quart. J. Mech. Appl. Math.
REVIEW OF SCIENTIFIC INSTRUMENTS AMERICAN INSTITUTE OF PHYSICS, 335 E. 45TH ST., NEW YORK, N.Y. 10017	Rev. Sci. Instr.
RUSSIAN ENGINEERING JOURNAL (English Translation of Vestnik Mashinostroeniya) PRODUCTION ENGINEERING RESEARCH ASSOC., MELTON MOWBRAY, LEICESTERSHIRE, ENGLAND	Russ. Engr. J.
SAE PREPRINTS SOCIETY OF AUTOMOTIVE ENGINEERS, TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001	SAE Prepr.
SAE TRANSACTIONS SOCIETY OF AUTOMOTIVE ENGINEERS, TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001	SAE Trans.
SHIPBUILDING AND MARINE ENGINEERING INTERNATIONAL WHITEHALL TECHNICAL PRESS, LTD. WROTHAM PLACE, WROTHAM, SEVENOAKS, KENT, ENGLAND	Shipbldg. Marine Engr. Int.
SIAM JOURNAL ON APPLIED MATHEMATICS SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, 33 S. 17TH ST., PHILADELPHIA, PA 19103	SIAM J. Appl. Math.
SIAM JOURNAL ON NUMERICAL ANALYSIS SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, 33 S. 17TH ST., PHILADELPHIA, PA. 19103	SIAM J. Numer. Anal.
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, NEW YORK, TRANSACTIONS SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, 20TH AND NORTHHAMPTON ST. EASTON, PA.	Soc. Naval Architects Marine Engr., Trans.

PUBLICATION AND ADDRESS	ABBREVIATION
SOVIET APPLIED MECHANICS (English Translation of Prikladnaya Mekhanika) FARADAY PRESS, 84 FIFTH AVE., NEW YORK, N.Y. 10011	Sov. Appl. Mech.
SOVIET PHYSICS, ACOUSTICS (English Translation of Akusticheskii Zhurnal) AMERICAN INSTITUTE OF PHYSICS, 333 E. 45TH ST., NEW YORK, N.Y. 10017	Sov. Phys. Acoust.
STRUCTURAL ENGINEER INSTITUTION OF STRUCTURAL ENGINEERS, 11 UPPER BELGRAVE ST., LONDON SW1, ENGLAND	Struc. Engr.
S/V, SOUND AND VIBRATION ACOUSTIC PUBLICATIONS INC., 27101 E. OVIAT RD., BAY VILLAGE, OHIO 44140	S/V, Sound Vib.
TECHNICAL REPORTS OF THE OSAKA UNIVERSITY FACULTY OF TECHNOLOGY, OSAKA UNIVERSITY, MIYAKOJIMA, OSAKA, JAPAN	Tech. Rept. Osaka Univ.
TECHNIK (BERLIN) VEB VERLAG TECHNIK, 102 BERLIN, ORANIBENBURGER STR. 12/14, GERMANY	Technik (Berlin)
TECHNOLOGY REPORTS OF THE TOHOKU UNIVERSITY, SENDAI, JAPAN FACULTY OF ENGINEERING, TOHOKU UNIVERSITY SENDAI, JAPAN	Tech. Rept. Tohoku Univ.
TRANSACTIONS OF THE AMERICAN SOCIETY OF LUBRICATING ENGINEERS ACADEMIC PRESS, 111 FIFTH AVE., NEW YORK, N.Y. 10017	Trans. Amer. Soc. Lubric. Engr.
TRANSACTIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS UNITED ENGINEERING CENTER 345 E. 47TH ST., NEW YORK, N.Y. 10017	
JOURNAL OF APPLIED MECHANICS	J. Appl. Mech., Trans. ASME
JOURNAL OF BASIC ENGINEERING	J. Basic Engr., Trans. ASME
JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT, AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME
JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engr. Indus., Trans. ASME
JOURNAL OF ENGINEERING MATERIALS AND TECHNOLOGY	J. Engr. Matl. Tech. Trans. ASME
JOURNAL OF ENGINEERING FOR POWER	J. Engr. Power, Trans. ASME
JOURNAL OF FLUIDS ENGINEERING	J. Fluids Engr., Trans. ASME
JOURNAL OF HEAT TRANSFER	J. Heat Transfer, Trans. ASME
JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech., Trans. ASME
TRANSACTIONS OF THE INSTITUTION ENGINEERS AND SHIPBUILDERS IN SCOTLAND W. R. STEWART (ED.) 183 BATH ST., 7 GLASGOW, C2, SCOTLAND	Trans. Instn. Engr. Shipbldg. Scotland
TRANSACTIONS OF THE INSTRUMENT SOCIETY OF AMERICA INSTRUMENT SOCIETY OF AMERICA, 400 STANDIX ST., PITTSBURGH, PA 15222	Trans. Instr. Soc. Amer.
TRANSACTIONS OF THE NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS NORTH EAST COAST INSTITUTION OF ENGINEERS, BOLBEC HALL, NEWCASTLE UPON TYNE 1, ENGLAND	Trans. North East Coast Inst. Engr. Shipbldg.
ULTRASONICS ILIFFE SCIENCE AND TECHNOLOGY PUBLICATIONS, INC., 300 E. 42ND ST., NEW YORK, N.Y. 10017	Ultrasonics
UNITED STATES CONGRESS ON APPLIED MECHANICS	U.S. Cong. Appl. Mech.
UNITED STATES NAVAL RESEARCH LABORATORIES, THE SHOCK AND VIBRATION BULLETIN SHOCK AND VIBRATION INFORMATION CENTER, NAVAL RESEARCH LAB., WASHINGTON, D.C. 20375	U.S. Naval Res. Lab., Shock Vib. Bull.
VDI FORSCHUNGSHEFT VEREIN DEUTSCHER INGENIEUR GMBH POSTFACH 1139, GRAF-RECKE STR. 84, 4 DUESSELDORF 1, GERMANY	VDI Fachungsheft
VDI ZEITSCHRIFT VERIN DUETSCHER INGENIEUR GMBH POSTFACH 1139, GRAF-RECKE STR. 84, 4 DUESSELDORF 1, GERMANY	VDI Z.
VEHICLE SYSTEMS DYNAMICS SWETS AND ZEITLINGER N.V. PUBLISHING DEPT. 347 B HERREWEG LISSE, NETHERLANDS	Vechicle Syst. Dyn.
WORLD CONGRESS ON APPLIED MECHANICS	World Cong. Appl. Mech.
ZEITSCHRIFT FUER ANGEWANDTE MATHMATIK UND MECHANIK AKADEMIE VERLAG GMBH 108 BERLIN, LEIPSIGER STR. 3-4, GERMANY	Z. Angew.
ZEITSCHRIFT FUER FLUGWISSENSCHAFTEN VEREIN DEUTSCHER INGENIEUR GMBH POSTFACH 1139, GRAF-RECKE STR. 84, 4 DUESSELDORF 1, GERMANY	Z. Flugwiss

CALENDAR

MEETING	DATE	LOCATION	CONTACT
	1977 FEB		
Automotive Engineering Congress and Exposition (SAE Annual Meeting), SAE	28-4	Detroit, MI	SAE Hq.
Symposium on Biodynamic Models and Their Applications, CHABA of NAS-NRC	15-17	Dayton, OH	G. Thomas Collins, Univ. of Dayton Dayton, OH 45469
	MAR		
Gas Turbine Conference and Products Show, ASME	27-31	Philadelphia, PA	ASME Hq.
Joint Railroad Conference, IEEE/ASME	30-2	Washington, D.C.	IEEE Hq.
	APR		
American Power Conference, Ill. Inst. Tech.	18-20	Chicago, IL	R.A. Budenholzer, Dir. APC c/o IIT, 10 W 35th St. Chicago, IL 60616
Design Engineering Conference and Show, ASME	18-21	New York, NY	ASME Hq.
Mini-Conference on Transportation	19-21	Ann Arbor, MI	Highway Safety Research Institute The University of Michigan Ann Arbor, MI 48109 Tele. (313) 764-2168
Diesel and Gas Engine Power Conference and Exhibit, ASME	24-28	Dallas, TX	ASME Hq.
IES Annual Meeting	24-27	Los Angeles, CA	IES Hq.
International Conference - Tribology	April	Cambridge, MA	Lt. R.S. Miller, Code 211 Office of Naval Research Ballston Tower No. 1 Arlington, VA 22117 Tele. 692-4421
	MAY		
31st Annual Technical Conference, ASQC	16-18	Philadelphia, PA	R.W. Shearman, ASQC Hq.
93rd Meeting of the Acoustical Society of America	17-20	State College, PA	J. C. Johnson, Chairman, ASA
Structures, Structural Dynamics and Materials Conference, AIAA	May		AIAA Hq.
	JUNE		
Fuels and Lubricants Meeting, SAE	7-9	Tulsa, OK	SAE Hq.
Applied Mechanics Conference, ASME	14-16	New Haven, CT	ASME Hq.
Lubrication Symposium, ASME	June	St. Louis, MO	ASME Hq.

CALENDAR			
MEETING	DATE	LOCATION	CONTACT
	1977 SEPT		
Vibrations Conference, ASME	26-28	Chicago, IL	ASME Hq.

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS:	American Federation of Information Processing Societies 210 Summit Ave., Montvale, N.J. 07645
AGMA:	American Gear Manufacturers Association 1330 Mass. Ave., N.W. Washington, D.C.
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, N.Y. 10019
AIChE:	American Institute of Chemical Engineers 345 E. 47th St. New York, N.Y. 10017
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, Ill. 60605
AHS:	American Helicopter Society 30 E. 42nd St. New York, N.Y. 10017
ARPA:	Advanced Research Projects Agency
ASA:	Acoustical Society of America 335 E. 45th St. New York, N.Y. 10017
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, N.Y. 10017
ASME:	American Society of Mechanical Engineers 345 E. 47th St. New York, N.Y. 10017
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, Ill. 60202
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, Wis. 53203
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, Pa. 19103
CCCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada
IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, N.Y. 10017
IES:	Institute Environmental Sciences 940 E. Northwest Highway Mt. Prospect, Ill. 60056
IFToMM:	International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME, Amherst, Mass. 01002
INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch, Poughkeepsie, N.Y. 12603
ISA:	Instrument Society of America 400 Stanwix St., Pittsburgh, Pa. 15222
ONR:	Office of Naval Research Code 40084, Dept. Navy, Arlington, Va. 22217
SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, Pa. 15096
SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, England
SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, Conn. 06880
SNAME:	Society of Naval Architects and Marine Engineers, 74 Trinity Pl. New York, N.Y. 10006
SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375
URSI-USNC:	International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, Mass. 02173